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# UNITED STATES FOREIGN POLICY

## POSSIBLE NONMILITARY SCIENTIFIC DEVELOPMENTS AND THEIR POTENTIAL IMPACT ON FOREIGN POLICY PROBLEMS OF THE UNITED STATES

## A STUDY

PREPARED AT THE REQUEST OF THE

COMMITTEE ON FOREIGN RELATIONS
UNITED STATES SENATE

BY

STANFORD RESEARCH INSTITUTE

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# PREFACE

**By Senator J. W. Fulbright, Chairman,**
**Committee on Foreign Relations**

In January of 1958 the Committee on Foreign Relations decided to undertake a review of conditions and trends in the world and of the policies and programs of the United States with respect thereto. That review grew, in part at least, out of the concern of the committee over the impact which Soviet scientific achievements might have upon our relations with the rest of the world.

From time to time throughout the spring of 1958, the committee held public hearings on U.S. policies respecting the Far East, the Near East, South Asia, Africa, Europe, Latin America, and Canada. Those hearings were limited in nature and served primarily to focus attention on the principal policies and problems of the United States in its relations with the rest of the world. For the most part, the hearings were limited to receiving testimony from the principal officers of the Department of State concerned with various geographic parts of the world. The committee also sought the testimony of selected nongovernmental witnesses with special knowledge of the areas under examination.

The hearings during the spring of 1958, the focus given to our relations with Latin America as a result of Vice President Nixon's visit there, and, lastly, the then critical situation in the Middle East, all contributed to the committee's belief that the time had come for an exploration in depth of U.S. foreign policies throughout the world.

As a consequence of these factors, the Committee on Foreign Relations, in an executive session on May 20, 1958, authorized its Subcommittee on American Republics Affairs to undertake a study of U.S.-Latin American relations. At the same time the committee established a special subcommittee, consisting of Senators Green, Fulbright, Wiley, and Hickenlooper, and directed it to explore the feasibility and desirability of a broad study of U.S. foreign policy throughout the world.

Subsequently, this subcommittee reported to the full Committee on Foreign Relations that it was feasible and desirable that the committee undertake such a study of foreign policy. It was felt a study of this nature might serve to develop fresh ideas and approaches to the foreign policy of the Nation and lead to a better national understanding of international problems and to more efficient and effective administration of our international operations.

On July 15, 1958, the Committee on Foreign Relations voted to report to the Senate a resolution authorizing the study. The Senate adopted this resolution (S. Res. 336, 85th Cong., 2d sess.) on July 31, 1958. The resolution authorized the Committee on Foreign Relations to "make a full and complete study of U.S. foreign policy." Without limiting the scope of the study authorized, the committee was instructed to direct its attention to the following subjects:

1. The concepts which govern the relations of the United States with the principal nations and geographic areas of the world, and the policies by which these concepts are pursued;

2. The present state of the relations of the United States with the principal nations and geographic areas of the world;

3. The administration and coordination of policies and programs by the Department of State and such other departments and agencies of the executive branch which engage in substantial activities abroad; and

4. The relationship of other policies and activities of the Government and private activity which exert a significant influence on the relations of the United States with the rest of the world.

In the conduct of its study the committee was authorized to "use the experience, knowledge, and advice of private organizations, schools, institutions, and individuals * * *" and to "enter into contracts for this purpose." It was directed to complete its study by June 1960, and not to exceed $300,000 was made available to meet the expenses of the committee. The committee was authorized to continue this study by the terms of Senate Resolution 31 (86th Cong., 1st sess.).

Shortly after Senate Resolution 336 was adopted by the Senate, Senator Green, then chairman of the Committee on Foreign Relations, designated me to serve as chairman of an executive committee, consisting of Senators Sparkman, Hickenlooper, and Aiken, which was given the responsibility for directing and coordinating the study.

On September 16 and 17, 1958, the executive committee discussed with a group of distinguished private citizens the general problems involved and the most advantageous approaches to them. Taking part in these discussions, besides the members of the executive committee, were Robert Bowie of Harvard University, former Ambassador William G. Bullitt, Robert Calkins of the Brookings Institution, John Cowles of the Minneapolis Star and Tribune, William Diebold of the Council on Foreign Relations, Henry Luce of Time-Life, Inc., Walter Millis of the Fund for the Republic, and Dean Rusk of the Rockefeller Foundation.

Following these meetings, the executive committee developed its plans and announced, on October 15, that it was prepared to invite private research organizations and institutions to submit proposals on a series of 15 studies which the committee expected to have undertaken in connection with its examination of foreign policy. As a result of this announcement, the committee received over 50 proposals from organizations and institutions interested in undertaking one or more of these studies.

On January 5, 1959, the executive committee met again to consider the proposals which had been received and decided which organizations and institutions should be asked to undertake studies for the committee. Set forth below are the titles of the studies designated to be undertaken and the names of the organizations and institutions responsible for these studies.

STUDIES

Study I–A. The Nature of Foreign Policy and the Role of the United States in The World. Council on Foreign Relations, Inc., 58 East 68th Street, New York, N.Y.

Study I–B. The Operational Aspects of U.S. Foreign Policy. Maxwell Graduate School of Citizenship and Public Affairs, Syracuse University, Syracuse, N.Y.

Study II. The Principal Ideological Conflicts, Variations Thereon, Their Manifestations, and Their Present and Potential Impact on the Foreign Policy of the United States. Center for International Affairs, Harvard University, 6 Divinity Avenue, Cambridge, Mass.

Study III. Worldwide and Domestic Economic Problems and Their Impact on the Foreign Policy of the United States. Corporation for Economic and Industrial Research, Inc., 1200 Jefferson Davis Highway, Arlington, Va.

Study IV. Foreign Policy Implications for the United States of Economic and Social Conditions in Lesser Developed and Uncommitted Countries. Center for International Studies, Massachusetts Institute of Technology, Cambridge, Mass.

Study V. Possible Developments in Military Technology, Their Influence on Strategic Doctrine, and the Impact of Such Developments on U.S. Foreign Policy. Washington Center of Foreign Policy Research, the Johns Hopkins University, 1906 Florida Avenue NW., Washington, D.C.

Study VI. Possible Nonmilitary Scientific Developments and Their Potential Impact on Foreign Policy Problems of the United States. Stanford Research Institute, Menlo Park, Calif.

Study VII. The Role of Multilateral Organizations in the Formulation and Conduct of U.S. Foreign Policy. The Brookings Institution, 722 Jackson Place NW., Washington, D.C.

Study VIII. Formulation and Administration of U.S. Foreign Policy. The Brookings Institution, 722 Jackson Place N.W., Washington, D.C.

Study IX. U.S. Foreign Policy in Western Europe. Foreign Policy Research Institute, University of Pennsylvania, Philadelphia, Pa.

Study X. U.S. Foreign Policy in the U.S.S.R. and Eastern Europe. The Russian Institute, Columbia University, New York, N.Y.

Study XI. U.S. Foreign Policy in the Near East. Institute for Mediterranean Affairs, Inc., 27 East 62d Street, New York, N.Y.

Study XII. U.S. Foreign Policy in South Asia. Conlon Associates, Ltd., 310 Clay Street, San Francisco, Calif.

Study XIII. U.S. Foreign Policy in Africa. African Studies Program, Northwestern University, Evanston, Ill.

Study XIV. U.S. Foreign Policy in the Far East and Southeast Asia. Conlon Associates, Ltd., 310 Clay Street, San Francisco, Calif.

Each of these organizations and institutions will submit a study to the committee.

Broadly speaking, I hope these studies will supply essential background to enable the Committee on Foreign Relations to accomplish the following basic purposes:

1. Provide the Senate and the American people with a simple, understandable, and forthright statement of the basic foreign policy aims of the United States which reflects the motivations and aspirations of the American people.

2. Identify those forces, domestic as well as foreign, which now or in the future may tend to frustrate or to promote the basic foreign policy aims of the United States.

3. Suggest, and if possible, determine, feasible ways to deal with such forces so that they may promote the basic foreign policy aims of the United States.

4. Examine the impact of those forces and trends, foreign and domestic, upon the conduct of American foreign policy in the various geographic areas of the world.

5. Examine the foreign policy decision-making machinery to determine whether it is of the maximum efficiency consistent with our democratic processes.

At the January 5 meeting the executive committee also decided to send a letter to some 50 retired Foreign Service officers "to endeavor to obtain for the use of the committee the personal views of men of practical experience with respect to the foreign policy of the United States." Each of these retired Foreign Service officers was asked to give the committee his "general commentary on what is right with our policies, what is wrong with our policies, and what action (or inaction) might in your opinion best serve our interest in the future."

On June 15, 1959, the committee made public, in a summarized form and without personal attribution, the substance of the views of former members of the Foreign Service who responded to the letter. The views and attitudes expressed in that committee publication deserve the most careful consideration by officials in the executive branch of the Government, by my colleagues in the Senate, and by all citizens interested in the conduct of our foreign policy.

The study printed in this volume, "Possible Nonmilitary Scientific Developments and their Potential Impact on Foreign Policy Problems of the United States," is the second of the 15 principal studies the committee expects to publish.[1] It was designed to help the committee find answers to subjects covered in an outline developed in consultations between representatives of the committee and representatives of the Stanford Research Institute. A copy of the outline appears in the appendix (see p. 99).

I take this occasion to emphasize that the studies which are received will supply the committee with background material for consideration in preparing a final report to the Senate. The committee is, of course, free to accept or to reject the findings and recommendations of the organizations and institutions submitting studies. It is the function of the committee to evaluate the studies which are submitted. Prior to the preparation of a final report, the committee will hold public hearings to receive testimony from all interested parties. In that way it will be possible for the committee to test the soundness of the findings and recommendations in these studies before reaching its own conclusions and submitting its final report to the Senate.

In addition, I wish to emphasize that the committee is approaching this assignment in a nonpartisan manner, endeavoring to avoid transitory issues and to concentrate on the fundamental forces at work within and without the United States which must be understood if our foreign policy is to serve the Nation.

[1] Study No. 1, "Worldwide and Domestic Economic Problems and Their Impact on the Foreign Policy of the United States," was published as a committee print in August 1959.

## LETTER OF TRANSMITTAL

STANFORD RESEARCH INSTITUTE,
*Menlo Park, Calif., July 24, 1959.*

Senator J. W. FULBRIGHT,
*Chairman, Committee on Foreign Relations,*
*U.S. Senate, Washington, D.C.*

DEAR SENATOR FULBRIGHT: I am pleased to enclose 25 copies of a report entitled "Science and Foreign Policy." This report explores prospective scientific developments of the next decade and their potential impact on foreign policy problems of the United States. It also explores the possibility of making more positive use of science and technology to help meet foreign policy problems.

The report does not examine developments in military technology, except for brief discussion of possible scientific contributions to problems of disarmament. We understand that military technology is being dealt with in another of the studies now being prepared for your committee. Furthermore, the report is not oriented toward certain important activities which have already been the subject of considerable discussion and action within the Government, such as scientific exchanges and the role of scientific attachés abroad, the role of international scientific organizations, and U.S. support of scientific activities overseas.

This report has been prepared in accordance with our contract agreement dated January 24, 1959, pursuant to the provision of Senate Resolution 31, 86th Congress, 1st session.

In the preparation of the report about 80 staff members of Stanford Research Institute provided guidance in their special scientific fields to the two authors, Dr. Eugene Staley and Mr. Guy Benveniste. The authors also received considerable advice and guidance from many other scientists and professionals in both academic and public life. This report has been prepared on the basis of published and unclassified sources.

It is our hope that the report may be of use to you, to your committee, and to our Nation as we all face the tasks of the future.

Sincerely yours,

E. FINLEY CARTER, *President.*

# POSSIBLE NONMILITARY SCIENTIFIC DEVELOPMENTS AND THEIR POTENTIAL IMPACT ON FOREIGN POLICY PROBLEMS OF THE UNITED STATES

## I. SUMMARY OF FINDINGS

I. *Scientific developments in the next decade will give rise to or intensify many problems that must engage the attention of foreign policy planners. Scientific developments will also help solve foreign policy problems. But the outlook is that the progress of science and technology will do more to create or intensify than to ameliorate such problems, unless deliberate policy measures are taken.*

### A. PROBLEMS FROM NEW ACTIVITIES THAT TRANSCEND NATIONAL BOUNDARIES

In the coming decade, science and technology will provide new means to use the vast resources of the oceans, to exploit the Arctic and Antarctic, to explore space, perhaps to affect climates. Unless better ways of cooperation are established, these advances into new frontiers will intensify international tensions. Current concepts of national sovereignty are not well suited to the orderly regulation of these advances nor to their development for maximum utility with minimum conflict. Policy planners will find it increasingly necessary to explore new types of supranational organization.

It is important to make sure that the United States advances rapidly in fundamental knowledge about these new frontiers and in imaginative new approaches to their utilization.

### B. PROBLEMS FROM POPULATION GROWTH AND THE REVOLUTION OF RISING EXPECTATIONS

It is most likely that in the coming decade the explosive growth of population in many parts of the world will be accelerated by new scientific advances in public health and medicine. At the same time the revolution of rising expectations in underdeveloped countries will be further heightened by continued advances in communications and by the competition of Communist nations. This combination of pressures will lead to social unrest or even war unless the resources of science can be more effectively brought to bear on world problems of food, economic and social development, and population control.

Most important in meeting world food problems will be action to hasten the spread of known methods of food production, or suitable adaptations of them, to areas of chronic need. New, unconventional ways of producing food may become feasible if scientific and technological breakthroughs are achieved, such as finding new sources of protein or controlling photosynthesis, to mention only two possibilities.

Many scientific disciplines can contribute effectively to meeting the problems of world economic development. Of greater importance than totally new discoveries and inventions will be (1) adaptations of known science and technology to the particular conditions of underdeveloped countries; and (2) progress in understanding the psychological and social problems related to diffusion of new production methods and to guidance of the economic, social, and political processes of development.

No miracles should be expected from the prospective scientific and technological advances. Under present allocations of effort to research and diffusion of results, the outlook is that the urgency of the problems will increase faster than the means of meeting them. There is nothing to suggest complacency in the face of the world's threatening population and production problems.

With the passage of time, population control will therefore become imperative; the population problem is already acute in some parts of the world. Current scientific developments indicate that a radical advance in techniques, such as a safe, effective, and inexpensive oral contraceptive, could soon be available if the comparatively small amount of research now underway in this field were stepped up. Greater than the physical and biological problems of birth control are the psychological and social problems to be solved if population growth is to be checked by methods other than famine, disease, and war.

### C. PROBLEMS OF ENERGY, MATERIALS, SYNTHETICS, AND TRADE

Advances in science and technology will in the next decade probably continue to increase America's growing dependence on foreign sources of raw materials and energy, including petroleum.

Scientific and technological advances will bring the partial or total displacement of a number of natural products by synthetics. Synthetics, or substitutes, will compete more intensively with rubber, leather, and fibers (cotton, wool, flax, hemp, jute, etc.). It is very likely that a synthetic or substitute coffee will be produced in the near future.

Some of these products are highly important as foreign exchange earners and sources of employment in friendly countries whose welfare affects the security of the United States. It is staggering to realize that such displacements could have major repercussions in at least 15 non-Communist nations. Foreign policy planners need to consider well in advance what steps might be taken to lessen the adverse effects of these possibilities.

The spread of modern science and technology, bringing new production methods of underdeveloped, low-wage countries, will create both new competition and new market opportunities for U.S. producers. The problems of trade policy which will therefore arise deserve advance study and planning.

It would be wise for the United States to initiate, preferably in cooperation with other nations and international agencies, a forward-looking study of world prospects for production and consumption of important raw materials and finished goods. Anticipation of changing trade patterns would aid U.S. producers and the U.S. Govern-

ment, as well as producers and governments of other nations, to respond more foresightedly.

### D. PROBLEMS OF INTERNATIONAL COMMUNICATION

Science and technology promise ample technical means to care for the anticipated increases in world communication needs. The real problems will be in the realm of policy; present U.S. policies regarding international communications need restudy and overhauling to meet the problems of the future.

Significant developments affecting international communications will result in the next decade from continued advances in physical techniques and facilities and also from advances in the sciences of human behavior relating to mechanisms of individual or group motivation and to meaningful interchange between members of diverse cultures. Developments such as low-cost mass communication devices, translating machines, and teaching machines will provide new opportunities to diffuse knowledge and ideologies. Brain chemistry and the study of brain mechanisms may open up powerfully beneficial and yet potentially dangerous means to control minds.

These developments will be available to both totalitarian and democratic societies. A problem of increasing importance will be to decide how the United States can use the new possibilities offered by the sciences related to communication in ways consistent with democracy and concern for human freedom.

II. *The national interest requires a more conscious direction of scientific activity in ways likely to assist in the achievement of America's international goals. The security and well-being of the United States call for a reappraisal of present allocations of scientific and technological effort with a view to directing more effort toward nonmilitary foreign policy challenges.*

### A. DELIBERATE USE OF SCIENCE

It is feasible, within limits, to think out what kinds of discoveries and inventions are needed and then, by deliberate policy, to stimulate the desired types of development. This is being done in military defense, industry, agriculture, and medicine. While some efforts along these lines are now being made in relation to nonmilitary aspects of foreign policy, the present orientation of the national scientific effort is insufficiently directed to this field. This is a grave matter in view of all that hinges on a successful American foreign policy.

The present allocation of scientific research and development efforts in the United States and in the world at large is overwhelmingly toward military needs and toward the needs of industry in technologically advanced countries. The emphasis is also overwhelmingly on the physical sciences and their applications, with the biological sciences and their applications second and the psychological and social sciences and their applications very far behind in allocations of effort and support. In view of the fact that foreign policy problems are mainly problems in human relations, this gross imbalance in research effort should be given thoughtful attention.

### B. STEPS THE COMMITTEE ON FOREIGN RELATIONS COULD TAKE

If the committee believes that it is desirable to use science more actively for the achievement of America's international goals, it could initiate a three-part program:

First, it could take steps in cooperation with the executive branch to stimulate additional research and development directed specifically at important problems in the formulation or execution of foreign policy. Eight examples of problems which merit such attention are given in chapter 7, and specific suggestions are put forward on two of these: arms control and disarmament, and development of underdeveloped countries.

Second, it could take steps in cooperation with the executive branch to bring about a doubling or tripling of the amount of basic scientific research in fields where progress in scientific understanding is particularly important to foreign policy. Because foreign policy problems are so largely problems in human relations, it is especially urgent to step up the basic research effort devoted to the psychological and social sciences.

Third, it could encourage the international proclivities of science and scientists in order to build bridges of understanding. Concrete suggestions are: more international scientific conferences and personnel interchange, international research programs, an international translation and scientific information retrieval center, a worldwide scientific research attack on the problems of economic and social development in an "International Development Year," and U.S. leadership to bring about the establishment of a United Nations university system.

III. *Foreign policy planning of the broadest kind, making use of the best scientific assistance, will be a critical requirement in the years ahead. This planning should include continual review of prospective scientific developments and their significance for international relations.*

If the United States is to use science in a more positive manner to support its foreign policy, policy planners will need access to and the aid of the scientific community, including that part of the scientific community concerned with psychological and social disciplines. Planners will need improved methods of analyzing future scientific, political, and economic possibilities, in order to create within the necessary leadtime the most appropriate policy alternatives to meet the rising tempo of new conditions.

Science and technology will probably advance even more rapidly in the coming decades and will increasingly alter the environment within which foreign policy must be formulated and executed. It is important to try to anticipate scientific developments in order to lessen the lag between new conditions and new policy responses. Any forecast of scientific developments and their effects is bound to be inadequate for periods more than a few years ahead. Therefore, provision is needed within the Government for continual review of scientific and technological possibilities in terms of their foreign policy implications.

## II. INTRODUCTION

### CHAPTER 1

### SCIENTIFIC DEVELOPMENTS AND FOREIGN POLICY

The problems confronting makers of foreign policy are almost totally different from what they would have been without the scientific developments of the last century, or even the last few decades. The scientific developments of tomorrow will pose new problems and will also offer new tools for dealing with foreign policy issues.

This report studies the impact of scientific developments (including technological applications of science) on the foreign policy problems of the United States and indicates areas in which scientific developments, consciously encouraged, can assist foreign policy. The discussion concentrates on nonmilitary aspects of scientific developments and of foreign policy. The time perspective is basically that of the next decade, the 1960's.

#### A. HOW SCIENTIFIC DEVELOPMENTS HAVE AFFECTED FOREIGN POLICY IN THE PAST

The direct and indirect consequences of scientific developments in the past have affected foreign policy at many points.

*1. Types of foreign policy consequences*

First, they have affected the basic aims and assumptions of foreign policy. Until the 20th century it was not unreasonable for the United States to seek to isolate itself from the politics of Europe and other distant continents. Now the conquest of distance, the revolution in production techniques, and consequent worldwide political and economic interdependence have made that impossible. In past centuries it was possible for statesmen to contemplate occasional wars among the great powers as more or less normal and acceptable features of the international state system. More recently the greater vulnerability of interdependent economies to wartime disruptions and, still more recently, the magnitude of destruction achievable with nuclear, chemical, biological, and other weapons have made total war between major powers the ultimate catastrophe to be avoided.

Second, scientific developments, along with other factors, have brought shifts in the actors and their roles in international relations and foreign policy. New production methods and their spread over the world have raised different nations to positions of power and influence—first Britain in modern times, later the United States itself, Germany, Japan, the Soviet Union, and China. New means of travel and communication have made people-to-people contacts increasingly important. Kings and states, or their ministers and diplomats, used to be considered the only important actors in inter-

national affairs. Today business corporations, private associations, tourists, even street mobs, may play significant roles.

Third, scientific developments have changed the relative importance of different geographic areas for foreign policy. The development of ways to use petroleum as a source of energy has increased the importance of petroleum-bearing areas like the Middle East. The development of still newer energy sources (nuclear, oil shale, solar) may in the future render them less important. Earlier developments in sea transport, naval warfare, and the needs of modern industry for overseas materials gave high strategic importance to canal areas and narrows, like Panama, Suez, and Gibraltar; aviation and missiles have in some respects altered this importance. Scientific explorations in polar regions and the voyage of the *Nautilus* have underlined the potential importance of areas hitherto of little concern to foreign offices, while artificial satellites have made policy planners conscious of the space beyond the earth's atmosphere.

Fourth, scientific developments have affected the subject matter with which foreign policy deals. Scientific progress itself has become a matter of concern to foreign policy makers, because of its important relation to military power, to economic relationships, and to a nation's prestige. The strategic and trade roles of various raw materials have shifted with new developments in science and technology. Lately new terms like uranium, zirconium, and titanium have invaded the reports of diplomats and trade departments.

Fifth, scientific developments have affected the instruments and methods of foreign policy. Instant communication, "telephone diplomacy," and quick travel—for personal conferences of foreign ministers or heads of state or meetings of important United Nations bodies—have given a new look to official international intercourse. Radio propaganda has become an important tool of international politics, and television may soon be important internationally. Satellite launchings and other technical and scientific accomplishments figure in international political maneuvers. Technical assistance and educational and scientific exchange programs are now recognized as important instruments of policy.

*2. Impact of science on attitudes*

Science has exerted an intangible but important long-term influence on foreign policy thinking through its impact on beliefs, values, and attitudes. For example, an initial effect of Darwin's discoveries about the evolution of life was apparently to strengthen European ethnocentrism. Some writers on evolution placed "savages," or even all "natives," in niches between the apes and the—from their point of view—obviously superior white Europeans. The doctrine of survival of the fittest was used to justify contemptuous and lordly attitudes toward Kipling's "lesser breeds without the law."[1] Later, scientific progress in anthropology, particularly cultural anthropology, along with the rise of "backward" peoples to political consciousness and power, wrought great changes. The present scientific view tends to discount claims of general racial superiority. Instead, it stresses cultural as well as biological evolution in accounting for the emergence of human societies and for the enormous range of techniques and codes of behavior observed in them. These developments in scientific

[1] See Loren Eiseley, "Darwin's Century," Garden City, N.Y., Doubleday, 1958, chs. XI and XII.

thought have had an impact on the course of policy with respect to colonialism, technical and economic assistance to underdeveloped countries, and related matters.

Scientific progress in the understanding of economic fluctuations and economic growth has affected man's outlook on foreign economic policy. Partly as a result of this better understanding, there is less disposition to accept international economic disasters as beyond human control, and there is greater demand for international programs to encourage economic and social advancement.

*3. Impact of science by way of technology*

By far the most important channel through which science has influenced the problems of foreign policy is technology. New technologies necessitating some form of international agreement or regulation have directly posed foreign policy problems. Radio communication made it necessary to seek international conventions on assignment of wavelengths. Aviation led to international controversies on air traffic rights, to a network of not entirely satisfactory agreements, and to an International Civil Aviation Organization. Nuclear energy, the new accessibility of polar regions, new prospects for exploiting ocean resources, and space exploration have created or are creating analogous problems of foreign policy. The production revolutions in industry and agriculture have had tremendous effects on international affairs. The shrinkage of distance brought about by modern transport and communication has altered the whole context of foreign policy.

Chart 1 shows the diminishing size of the world in travel time under the influence of successive technological developments. The top map of the same chart also approximately represents message time until nearly the middle of the 19th century. But today's world of electronic communication, drawn on the same time scale, would be microscopic.

The changes imposed on American foreign policy by these transformations in the world environment have been difficult and drastic. They have forced nearly complete abandonment of the mood that used to be called isolationism. Our Government, recognizing the new realities and pursuing policies which would have been acceptable only to a radical internationalist minority a few decades ago, now finds itself a leader in the United Nations and in a worldwide system of alliances.

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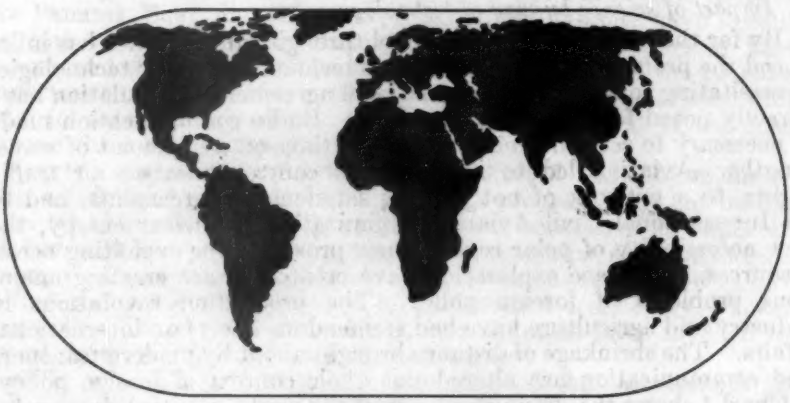
CHART 1

SIZE OF THE WORLD, IN TRAVEL TIME
Supposing the Best Travel Technology of Each Epoch
Were Applied over the Whole Surface of the Earth



STAGECOACH AND SAILING SHIP
TO 1830's AND '40's
BEST REGULAR SPEED ON LAND AND SEA 10 mph

COAL-STEAM RAILROAD AND STEAMSHIP
LATE NINETEENTH, EARLY TWENTIETH CENTURIES.
BEST REGULAR SPEED ON LAND 65 mph, ON SEA 36 mph

PROPELLER AIRCRAFT
TO 1950's
BEST REGULAR PASSENGER SPEED 300 mph

JET AIRCRAFT
FROM 1950's
REGULAR PASSENGER SPEEDS 500 mph AND UP

### B. CONNECTING LINKS BETWEEN SCIENCE AND FOREIGN POLICY

There is some danger of seeming to imply that foreign policy problems result only from scientific developments and that all the solutions have to be sought in the realm of science or its applications. No such impression is intended. Scientific developments certainly do not act on international relations in a deterministic way, independent of other forces and factors. For example, the international consequences of unlocking atomic energy might have been very different had this scientific triumph occurred, not during a world war and in a world of competing ideological blocs, but in some other situation. Realism requires emphasizing the interplay, in relation to foreign policy, between scientific developments and many other forces and factors. Among these are political systems, resources, the way in which production is organized and wealth distributed, values and emotions like those in nationalisms and religions, and the influence of strong personalities in positions of power. Though it sometimes seems that science and technology have become our masters rather than our servants, the controlling factors are still men's attitudes, desires, social intelligence, and wills.

There is also the danger in this report of inadvertently strengthening a popular tendency to confound science with its technological applications. For this report must speak more often of technological applications than of basic science. It will be worthwhile, therefore, to comment briefly on the relation between science and technology and to outline the sequence of interrelated stages by which science and technology affect and are affected by foreign policy.

*1. Science and technology*

By science is meant systematic knowledge and methods of discovering new knowledge, especially knowledge arranged in a logical structure of theory which is constantly under test and revision. By technology we mean a systematic body of methods for the achievement of human purposes in any field. Until modern times, technology consisted of the slowly accumulated lore of the practitioners of the various arts and crafts; it had comparatively little direct relation to science. Nowadays, advances in technology are often directly based on advances in science, and vice versa. More and more, technology is applied science.

It is convenient to group the many branches of science and technology into three major fields: physical, biological, and psychological and social (chart 2). The connections between science and technology are on the whole considerably more intimate today in the physical and biological fields than in the psychological and social fields. The technologist who designs a new space probe or a new hormone medicine or a new insecticide bases his work very directly on quite sophisticated theories which have been tested by the scientific method. This is considerably less true in the case of the social innovator—the legislator, the educational reformer, the foreign policy planner. The difference is due in part to the lesser development of the sciences of man, their lesser precision and authority, which is in turn explainable by the greater number and complexity of the variables these sciences have to deal with. In part, it is due to social attitudes. Since the days of the great controversies raised by Galileo

and Darwin, social attitudes have moved far toward universal acceptance of a scientific approach to physical and biological questions. But they remain more resistant to the idea of applying scientific methods for the analysis and possible reconstruction of emotionally valued human institutions.[2]

CHART 2

*Fields of science and technology*

| | Sciences | Corresponding technologies |
|---|---|---|
| Physical | Physics, chemistry, geology, astronomy, etc. | Techniques of transportation, communication (physical aspects), mining, working of materials, construction, weaponry, etc. |
| Biological | Botany, zoology, physiology, anatomy, microbiology, etc. | Techniques of crop growing, animal husbandry, medicine, etc. |
| Psychological and social | Psychology, sociology, cultural anthropology, economics, political science, etc. | Techniques of communication (social aspects), language, education, mental therapy, law, justice, business management, public administration, diplomacy, etc. |

*2. Processes linking science and social change*

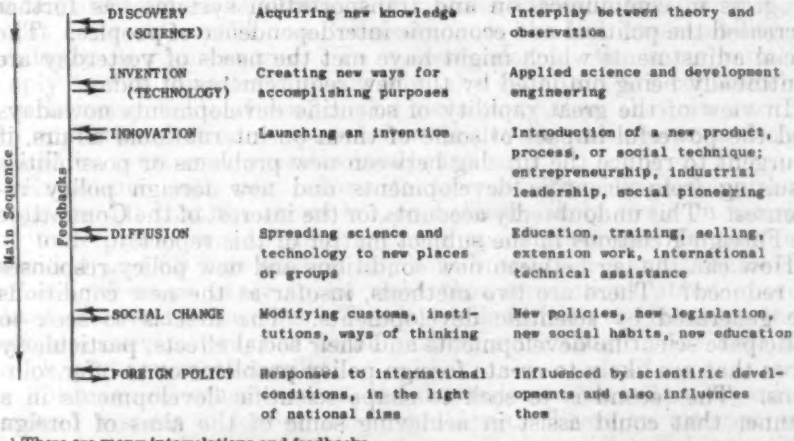
When the term "scientific development" is used in this report, the intention is to suggest the whole sequence depicted in chart 3. This shows the processes by which science and technology grow and spread and exert social effects, including effects on foreign policy. The main sequence of development moves from top to bottom in the diagram, that is, from scientific progress (discovery) through new technology (invention) through practical adoption and spread of the new ideas and techniques (innovation and diffusion) to economic, social, and political readjustments (social change), to impacts on foreign policy. The sequence, however, is really circular, for social, economic, and political factors, including military and other foreign policy considerations, exert a powerful influence on the direction of discovery and invention.

Someone has said that in recent times we have invented the art of systematic invention. Organized scientific research and development, which has become a great industry in the last few decades, is itself one of the most significant social inventions of the 20th century. It is unlocking the secrets of nature and putting the knowledge to practical use at an unprecedented rate. Also, we have invented the art of systematic innovation (as the term is used in chart 3); a large part of the business skill in some modern corporations is devoted to launching new products and processes, and the Armed Forces deliberately plan the obsolescence of their equipment. Further, we have invented and are applying the art of systematic international diffusion, through technical assistance and educational exchange programs. At each

[2] There are instances where this resistance has been broken down in a striking way, usually under authoritarian rule. Turkey under Ataturk, the Soviet Union, and Communist China come to mind. India is attempting, under democratic leadership, to consciously reconstruct its society as well as to build up its productive equipment. The same may be said of others among the underdeveloped countries now engaged in modernization, though in general the tendency mentioned in the text is visible, that is, greater readiness for conscious remodeling of physical facilities than of social institutions.

CHART 3

SEQUENCES WHICH LINK SCIENCE TO FOREIGN POLICY[1]




| | Meaning of Term | Further Explanation |
|---|---|---|
| DISCOVERY (SCIENCE) | Acquiring new knowledge | Interplay between theory and observation |
| INVENTION (TECHNOLOGY) | Creating new ways for accomplishing purposes | Applied science and development engineering |
| INNOVATION | Launching an invention | Introduction of a new product, process, or social technique; entrepreneurship, industrial leadership, social pioneering |
| DIFFUSION | Spreading science and technology to new places or groups | Education, training, selling, extension work, international technical assistance |
| SOCIAL CHANGE | Modifying customs, institutions, ways of thinking | New policies, new legislation, new social habits, new education |
| FOREIGN POLICY | Responses to international conditions, in the light of national aims | Influenced by scientific developments and also influences them |

[1] There are many interrelations and feedbacks.
Scientific discovery may directly induce social changes and foreign policy changes by altering the climate of ideas. Various kinds of social change encourage or retard scientific discovery or turn the attention of scientists to new fields.
Invention sometimes precedes discovery. For example, in animal husbandry the fact that mixing minute quantities of antibiotics in feedstuffs substantially increases the growth rate of poultry and pigs was observed and widely used before scientists could explain why it worked.
More and more, however, the main sequence is coming to be from progress in scientific understanding to achievement of desired technological applications, to their practical introduction and spread. This is the normal method of work in organized scientific research and development today.

stage in the sequences which link discovery to invention, innovation and diffusion, the links are being shortened and the processes speeded up.

*3. Lag in responses to changing conditions*

It takes time for human societies to readjust their ways of behaving and thinking to new conditions brought about by discoveries and inventions or by the diffusion of existing knowledge and techniques into societies that have not previously used them. Meanwhile, there is a period of maladjustment during which actions and thoughts are more appropriate to the old situation than to the new. This is the phenomenon that William F. Ogburn, sociologist and pioneer student of the impact of science and technology on society, has labeled "cultural lag."

International aviation, for example, created new needs for uniform signaling and safety regulations, traffic control, allocation of routes, and prevention of spread of diseases by fast-traveling passengers. It took time to meet these requirements; some of them are still imperfectly met.

Even before the First World War some leading thinkers believed that the growing interdependence of nations required a world political organization, but it took many years to gain acceptance for the idea of a League of Nations and then a United Nations. Meanwhile, scientific developments have led to vastly more effective weapons. Progress in communication and transportation systems has further increased the political and economic interdependence of peoples. The social adjustments which might have met the needs of yesterday are continually being outdated by the new requirements of today.

In view of the great rapidity of scientific developments nowadays and the powerful impact of some of them on international affairs, it is urgent to reduce the timelag between new problems or possibilities resulting from scientific developments and new foreign policy responses. This undoubtedly accounts for the interest of the Committee on Foreign Relations in the subject matter of this report.

How can the lag between new conditions and new policy responses be reduced? There are two methods, insofar as the new conditions are generated by scientific developments. The first is to seek to anticipate scientific developments and their social effects, particularly those that are likely to create foreign policy problems or to offer solutions. The second is to seek to shape scientific developments in a manner that could assist in achieving some of the aims of foreign policy.

### C. ANTICIPATING SCIENTIFIC DEVELOPMENTS

The prediction of scientific and technological developments, though a slippery business, is not entirely hopeless, as studies of some past efforts have shown.[3] A limited success is attainable, and this is useful.

The chance of successful prediction is likely to be greater the further down in the sequence of development processes (chart 3) we are working. Thus, in decreasing order of probability of successful prediction, we can attempt to anticipate—

1. Spread of existing knowledge and techniques and adaptations of them.
2. Introduction and spread of new techniques already invented (now in the laboratory or pilot stage).
3. Invention of new techniques likely to be possible on the basis of scientific principles already known.
   (*a*) Same, on the basis of scientific principles just being discovered and not yet fully worked out.
4. Discovery of presently unknown scientific principles, out of which new techniques may eventually come.

This report takes account of possibilities at all these levels, if the possibilities appear to have significance for foreign policy; the report does not, however, pretend to be exhaustive.

The most powerful effects in the long run are likely to come from the fourth level, and it is the least predictable. On the other hand,

[3] See S. C. Gilfillan, "The Prediction of Inventions," in National Resources Committee, "Technological Trends and National Policy," Washington, Government Printing Office, 1937, pp. 15–23.
Gilfillan carefully appraised quite a number of past forecasts in the light of subsequent developments. Among his conclusions: "Distinguished technical and scientific men, who choose to predict in their own general field, make the best seers of all. Yet they are liable to upsets from developments in outside lines, and from the tendency of the ordinary scientific or technical man to see little change ahead. For these are usually much impressed with the failure of all past inventors to achieve this and that, because of supposed scientific principles that bar the path."

there is usually a fairly long leadtime intervening between a radical new discovery and the social effects resulting from it. This gives an opportunity for advance notice of possible effects to come. It takes time to devise and test inventions applying the new principle, to introduce these practically, and to diffuse them widely. Therefore, anticipations of social effects no more than a decade ahead should, in most cases, not suffer too decisively from the low predictability of radically new discoveries. To a lesser degree, the same remarks apply to the third level. However, the time lags are considerably less in many fields of science and technology than they used to be. In any attempt to anticipate scientific developments even a decade ahead we must expect serious inadequacies.[4]

Experience with past efforts to forecast scientific developments suggests: (1) that the errors are, on balance, likely to lie on the side of underprediction, so long as pure speculation and fantasy are avoided; and (2) that predictions about broad trends and about social effects are more likely to be right than predictions about specific discoveries and inventions. This last follows from the fact that there are often several ways of accomplishing something; if one does not work, perhaps another will.[5]

For this and other reasons, the discussion in part 2 is organized around a series of foreign policy problems. There an attempt will be made to anticipate not so much specific discoveries and inventions as the trend and effects of scientific developments which seem likely to intensify or to help solve foreign policy problems.

### D. SHAPING SCIENTIFIC DEVELOPMENTS

To some extent organized society—through governments, business corporations, universities, foundations, and research institutes—exercises an influence on what will be discovered and invented, or at least partially determines in what fields the most discoveries and inventions will be made. This influence is exercised by the allocation

[4] To illustrate, consider the report "Technological Trends and National Policy" prepared for the National Resources Committee in 1937. It was a very sophisticated attempt, one of the best ever made, to analyze the impact of science and invention on social affairs and to look ahead "to show the kinds of new inventions which may affect living and working conditions in America in the next 10 to 25 years." It drew upon technologists and scientists in many fields as consultants. (The emphasis appears to have been more on engineers than on scientists.) The anticipations of the report can in most respects be rated reasonable and successful. And yet several most important developments of the subsequent 10 years eluded prediction. In terms of the discussion in the text above, the first of the items which follow was at level 4 in 1937, the others at level 3 or 3(a):

1. *Atomic energy.*—Though there was a chapter on power in the report, it contained no hint that atomic energy might someday be used for power or for anything else. There had been scientific speculation for years on possible tapping of atomic energy, but the scientific basis for realization of such ideas came only in 1939 with the discovery of nuclear fission. The first sustained nuclear chain reaction was achieved in 1942.

2. *Antibiotics.*—A chapter on chemical industries anticipated further developments in vitamins, hormones, and synthetic drugs but did not forsee antibiotics. The basic scientific discovery had already been made. Fleming, at Oxford in 1929, had observed and reported the bacteria-killing power of the mold which produces penicillin. Practical use of the discovery was delayed for 10 years, then touched off a great surge of antibiotic developments which within very few years had pronounced effects on medicine and society.

3. *Radar.*—Detailed chapters on communications and transportation, both of which dealt with radio aids to navigation, did not mention the possibility of a radio searchlight or radar—destined within 5 years to help turn the tide in the air battle over Britain. In 1937 the idea was just forming in the minds of certain scientists in Britain and the United States.

4. *Jet propulsion.*—The chapter on transportation foresaw faster passenger planes; speeds around 240 miles per hour at 20,000 feet were predicted, if the problem of pressurizing cabins could be solved. There was no inkling of jet propulsion, which appeared in aircraft before the end of World War II.

This history causes us to ask ourselves: What epochal discoveries and inventions of the 1960's comparable to atomic energy, antibiotics, radar, and jet propulsion are we missing?

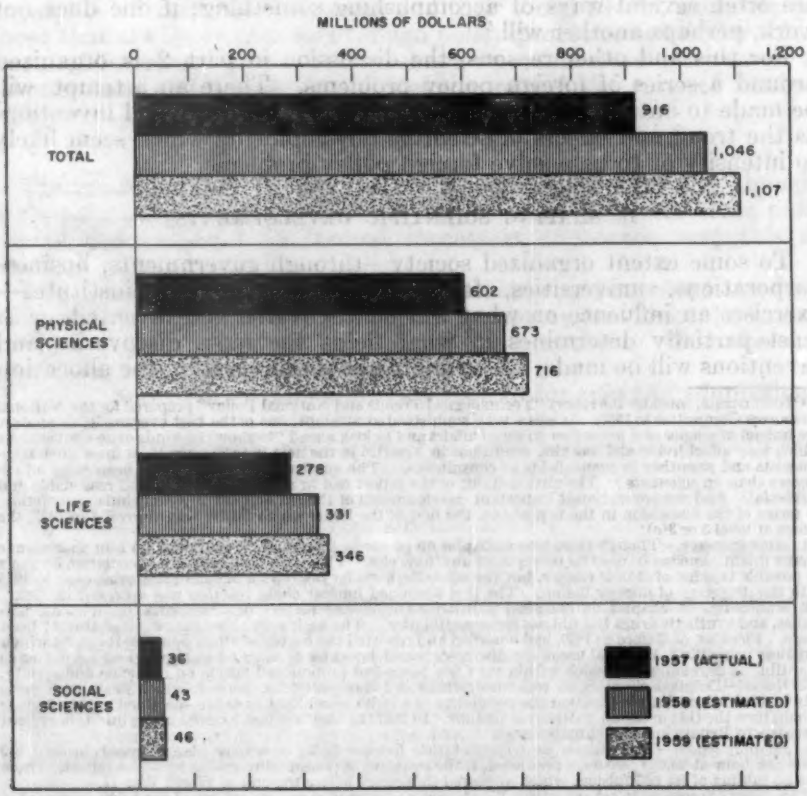
[5] Gilfillan, in his study on prediction of invention cited above, concludes that it is "easier to predict the effects than the inventions themselves." This is because of what he calls the principle of "functionally equivalent invention." For example, we are more likely to be right if we predict worldwide television hookups than if we predict that the means used will be reflection of signals from satellites. The effect may be achieved by any of several means. We are even more likely to be right if we say that the intensity of mass communication on a worldwide basis will increase markedly, thus including not only the possibility of worldwide television hookups but also other means of mass communication, perhaps means not yet thought of.

of funds (personnel and equipment) for research and development, and also by the allocation of rewards in the form of prestige and social approval.

The best information available about allocations of funds in the United States by broad fields of science is shown in chart 4 (Federal Government), chart 5 (universities), and chart 6 (foundations). Research expenditure in the fields of human behavior and social problems is quite small relative to that in the physical and biological fields. Only in the case of the foundations is there a different emphasis. Information from industry about allocation of research efforts by these same major fields is not available. The National Science Foundation's study of industrial research was limited to the natural sciences and

CHART 4

UNITED STATES FEDERAL GOVERNMENT OBLIGATIONS FOR RESEARCH, BY SCIENTIFIC FIELDS




SOURCE: National Science Foundation, Federal Funds for Science, VII. The Federal Research and Development Budget, Fiscal Years 1957, 1958, and 1959, Washington, Government Printing Office, 1958, p.13.

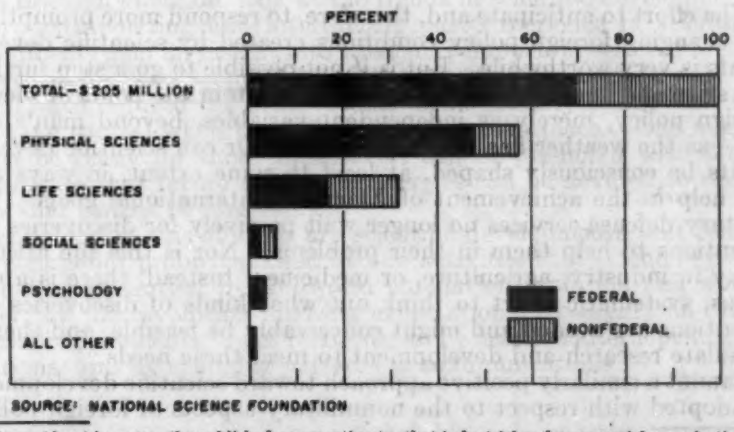
their applications—a revealing fact in itself.[6] It is safe to conclude that if comparable information were available from industry the broad picture would not be changed: research overwhelmingly directed toward the solution of physical and biological problems, with research on human behavior and social relations a very poor third.

What little is known about allocations for research in other countries suggests that the world picture would not be greatly different in this respect. The Soviet Union, for example, would certainly show a high concentration on physical sciences. As for the rewards of prestige and social approval, they probably strengthen, both in our own country and abroad, the pattern indicated by allocations of funds, with some modifications such as special social approval for medical achievements.

Insofar as the organized influence of society is effective—as expressed in present allocations of efforts and rewards, and assuming that these will not be substantially changed—the physical and biological sciences and technologies will develop much faster in the next decade than the psychological and social sciences and technologies. This will tend to increase the lag of adaptive social adjustments behind the onrushing advance of material power, in the foreign policy field and in other fields.

CHART 5

SEPARATELY BUDGETED RESEARCH EXPENDITURES
IN COLLEGES AND UNIVERSITIES, 1953 - 1954

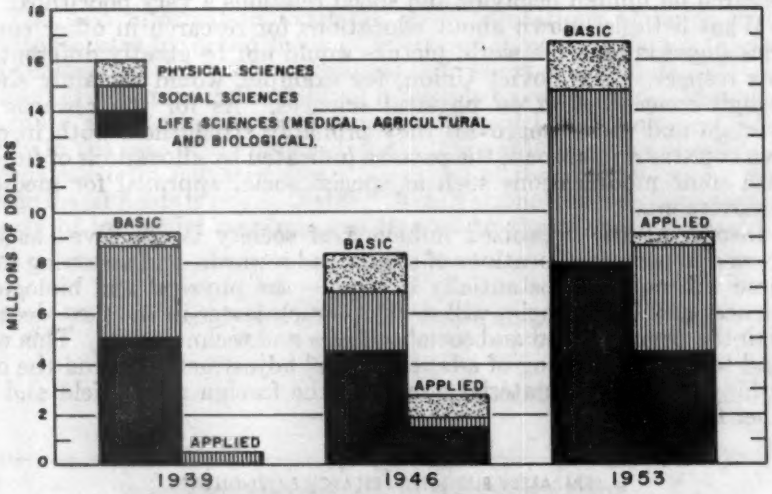



SOURCE: NATIONAL SCIENCE FOUNDATION

[6] Harry Alpert in a recently published paper estimates that industrial and commercial organizations are spending about $137,000,000 annually on social science research, of which some $125,000,000 is for opinion and attitude surveys and marketing research. Harry Alpert, "The Growth of Social Research in the United States," in Daniel Lerner (ed.), "The Human Meaning of the Social Sciences," New York, Meridian Books, 1959, pp. 73-86. Private industry in the United States spent an estimated $6.5 billion on research and development in the natural sciences and engineering in 1956 (National Science Foundation, "Reviews of Data on Research and Development," No. 10, May 1958, p. 1).

CHART 6

SUPPORT OF BASIC AND APPLIED RESEARCH
BY 77 LARGER FOUNDATIONS




SOURCE: NATIONAL SCIENCE FOUNDATION

The effort to anticipate and, therefore, to respond more promptly to the changing foreign policy conditions created by scientific developments is very worthwhile. But is it not possible to go a step further? Are scientific developments to be regarded, from the point of view of foreign policy, merely as independent variables, beyond man's control—as the weather has been up to now? Or can scientific developments be consciously shaped, at least to some extent, in ways that can help in the achievement of America's international goals? The military defense services no longer wait passively for discoveries and inventions to help them in their problems. Nor is this the attitude today in industry, agriculture, or medicine. Instead, there is a conscious, systematic effort to think out what kinds of discoveries and inventions are needed and might conceivably be feasible, and then to stimulate research and development to meet these needs.[7]

Cannot a similarly positive approach toward scientific developments be adopted with respect to the nonmilitary aspects of foreign policy?

[7] Such an active approach applies also to basic science, not merely to applied science. Mathematical or theoretical physics was almost exclusively European until the National Research Council started to foster it deliberately in the United States in the 1920's. Now the United States is at least as strong as any other nation in this subject.

## III. FUTURE FOREIGN POLICY PROBLEMS IN THE LIGHT OF SCIENTIFIC DEVELOPMENTS

We claim no sixth sense with which to foresee the future. The future examined in the following chapters is not the real future of the next decade—it is only a projection of existing knowledge into time, an indicator of what may result from forces already perceptible. As such, it is not a vision of the future, but simply a small window into time.

To really predict future scientific discoveries or future major inventions would require a prediction and evaluation of ideas that are still to form in the minds of men. But what can be done, and what has been tried in this study, is to look at some of the current ideas, look at the research going on, look at the trends in scientific development, and by extrapolating and interpreting past experience in scientific developments gain an insight into what may happen in selected areas.

If we can foresee a sector of the future and prepare ourselves for it, we will have reduced the total volume of uncertainty with which we shall have to deal when the unforeseen does take place. One might as well be ready for those things that can be predicted with some certainty, so that future talent and energies can be devoted to those things that cannot be foreseen.

Highlighted in this analysis are scientific developments that relate to foreign policy problems raised by new activities that extend beyond national sovereignties; by the world population explosion and world hunger; by the revolution of rising expectations; by energy and raw material requirements, trade relations, and economic interdependence of nations; and by changing patterns in communications.

## Chapter 2

# SCIENCE AND NATIONAL SOVEREIGNTY

In certain scientific areas, man is truly engaged in worldwide activities—activities that no longer can be contained within the scope of national boundaries. Advances into space, advances in communications, the possibility of influencing world climatic conditions, the possibilities of mining or harvesting the oceans, and the increasing problems resulting from contamination of air, sea, and land by industrial or radioactive sources all present problems that transcend national boundaries. These advances are bound to create new tensions, new misunderstandings, and new means for aggression between nations, as well as new opportunities for cooperation.

### A. NATIONAL BOUNDARIES

Modern concepts of national sovereignty are based on the existence of well-defined physical boundaries, easily identified and relatively well controlled. Our western concept of the boundary dates approximately from the time of Charlemagne's death, when feudal lands were subdivided and several parties agreed to definite partitions. Even today some societies do not recognize stable borders; certain tribes and nomad groups continue to live on the margin of sedentary cultures and essentially flout the artificial borders created by statesmen. Similarly, certain areas of the world are still unmapped, or relatively unexplored, and borders are not well defined.

While most of the land has been divided and partitioned, the freedom of the high seas has generally been recognized. Again, this has not always been so. Prior to the 17th century it was accepted that nations could claim sovereignty over any part of the high seas as long as they could enforce the claims. These national aspirations were dropped as nations were unable to enforce their claims, and freedom of the high seas was gradually established permitting world trade to expand.[1]

In the last 50 years aeronautics has raised new problems. A "free air" policy was advocated in certain quarters, but from the first international aviation conference held in Paris in 1919 to the Chicago aviation conference in 1944 creating the International Civil Aviation Organization, now a specialized agency of the United Nations, the emphasis has been on the concept of national sovereignty of the air, close government control of all aspects of air policy, and bilateral and international negotiation of international differences on vital questions.

[1] Still unsettled to date is the limit to territorial sovereignty over coastal waters. The Conference on the Law of the Sea held in Geneva in the spring of 1958 under the auspices of the United Nations considered among other things the claims by several nations, including the U.S.S.R., extending territorial limits from 3 to 12 miles. No agreement was reached. During the Conference the United States offered to extend rights to 6 miles, but this proposal was turned down. Since then, Iceland has extended its claim to exclusive fishery rights to 12 miles. The Conference did establish a convention on national rights over the Continental Shelf, thus providing the first worldwide accord on the subject.

Concepts of boundaries received a somewhat rude shock when space vehicles started circling the globe, independent of national controls maintained at lower altitudes. In recent years and months the U.S. Government has sought to clarify international problems arising from the use of outer space,[2] and has sought to devise new forms of international cooperation. House Concurrent Resolution No. 332, passed by the Senate in July 1958, stated:

> That the United States should seek through the United Nations or such other means as may be most appropriate an international agreement providing for joint exploration of outer space and establishing a method by which disputes which arise in the future in relation to outer space will be solved by legal, peaceful methods rather than by resort to violence.

The ad hoc committee of the United Nations established in December 1958 has already presented a report on the future problems of the peaceful use of outer space. Unfortunately, the Soviet Union and several other nations have not thus far participated in its work, on the ground that the Communist bloc had insufficient representation on the committee. The success or failure of the United Nations in this area will have considerable significance for the ability of man to use outer space peacefully.

Foreign policy problems will result from these advances that cannot be contained within national boundaries, as well as from undesirable byproducts of new scientific advances. These new problems will require cooperation between nations to avoid friction and tension. Such cooperation can best be achieved if it is worked out before the full impacts of the developments are with us.

### B. AIR AND SEA POLLUTION

The problems now being encountered by the Governments of the United States, the United Kingdom, and the Soviet Union as a result of radioactive fallout from nuclear tests have created new sources of international tension and brought strong demands for international agreement and cessation of these tests. National boundaries are fixed and well defined, but the movement of air masses throughout the globe evades control and identification. As a result, nuclear explosions in one country inevitably, even though unintentionally, affect conditions in another.

Radioactive fallout, a most insidious type of air pollution, has already produced numerous international complications; however, it is not the only form of pollution resulting from scientific and technological advances. International air and water pollution problems arising from industrial and urban concentrations are already well known and bound to increase.

Even if military bomb testing were brought under control, the potential pollution problems arising from nonmilitary nuclear explosions, from reactor wastes, and from worldwide increases in industrial and urban contamination would still require international cooperation and agreement. Unfortunately, we still know too little about the international effects of such contamination in the atmosphere and in the oceans.

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[2] One of the most immediate problem areas is the international legal complications concerning the use of space. An excellent account of these problems is given in the "Survey of Space Law," staff report of the Select Committee on Astronautics and Space Exploration, 86th Cong., 1st sess., House Doc. No. 89, Washington, 1959.

The atmosphere and the oceans are interacting systems. The oceans may be considered a global chemical sump; most manmade radioactivity and contamination ultimately accumulate there. Radioactivity in the sea is a matter of concern, since the oceans are major sources of food. At present very little is known of the radiochemistry and biology of the sea. Further international efforts in these fields, some of them already initiated by the International Geophysical Year and by the International Atomic Energy Agency, should provide a better understanding of problems to be faced in the future.

As waste materials from peaceful uses of atomic energy become important, it will be increasingly necessary to insure their safe disposal and to establish international standards of hazard and contamination. A number of studies in recent years have estimated, quite conservatively, the potential quantities and dangers inherent in waste accumulation from future peaceful uses of atomic energy.[3] These studies [4] indicate that (*a*) the quantity of peaceful waste material will within 25 to 50 years become sufficient to endanger mankind unless reliably stored, (*b*) there is insufficient information about the reliability of existing waste storage techniques, (*c*) there is little knowledge of the reliability of possible future waste storage techniques, (*d*) there is insufficient knowledge regarding the long-term impacts of intermittent small doses or continuous low levels of radiation on man.[5]

Since the peaceful uses of atomic energy are looked upon by much of mankind as a symbol of the opportunities to make a better world, and since waste disposal and operational hazards can create dangerous international accidents, the establishment of safe international standards of operation presents one of the most important challenges to the International Atomic Energy Agency [6] and to governments. This will be particularly true in a world where atomic ships, atomic explosives for peaceful uses, atomic power stations, and atomic heat provide new sources of inexpensive energy.

### C. WEATHER MODIFICATION AND CLIMATE CONTROL

A considerable amount of experience has been gained in localized cloud-seeding programs. In 1957 the Advisory Committee on Weather Control, after a careful statistical study, was able to conclude that the seeding of winter storm clouds in mountainous areas in the western United States produced an average increase in precipitation of 10 to 15 percent.[7] This report has been misunderstood sometimes, particularly in the popular press, where it has been called the proof that weather control is possible. This publicity has usually indicated a degree of success not supported by fact. The favorable results have been obtained only in selected areas and under favorable conditions;

[3] Such estimates are usually based on conservative calculations of atomic energy production and do not make allowance for the magnitude of waste and contamination resulting from nonpower uses such as the peaceful application of nuclear explosions to perform large excavations or to create useful subterranean cavities.

[4] For example, E. D. Arnold, "Economics and Hazards Potential of Radioactive Waste Disposal," paper presented before American Nuclear Society, Pittsburgh, Pa., June 1957; "Report of the United Nations Scientific Committee on the Effects of Atomic Radiation," General Assembly, 13th sess., Supplement No. 17 (A/3838), August 1958; "The Disposal of Radioactive Waste on Land," National Academy of Sciences, Pub. 519, 1957; "The Effect of Atomic Radiation on Oceanography and Fisheries," National Academy of Sciences, Pub. 551, 1957; hearings of the Joint Committee on Atomic Energy, 85th Cong.

[5] These problems are ably presented in a recent article by Wallace deLaguna, "What Is Safe Waste Disposal?", Bulletin of the Atomic Scientists, vol. XV, No. 1 (January 1959).

[6] The Agency established in October 1958 an international panel of experts to study problems connected with waste disposal in the sea.

[7] Final report of the Advisory Committee on Weather Control, Washington, Government Printing Office, 1957, vol. 1, p. vi.

the value of cloud seeding under other than ideal conditions is still in doubt. However, as one of the first attempts in the field, the experiments indicate that such alterations of weather are a definite possibility. They also point to the need for study of the indirect effects of such modification. For example, we do not know whether cloud seeding decreases rainfall in adjacent areas. Cloud seeding is believed to be effective in suppressing hail, but this effect has not yet been proved.

Other successful examples of weather modification fall in the field of fog and low cloud dispersion. The wartime use of oil fires to disperse fog (FIDO) was reasonably successful, if costly. More recently carbon black has been used to cause cloud droplets to absorb more sunlight and hence to be evaporated by the increased heating. This has been shown to be self-expanding after a large enough area has been cleared. The sunlight heats the ground under the cleared area; the ground in turn heats and evaporates the droplets around the perimeter of the clear area.

*1. Possibility of large-scale climate control*

We must distinguish between weather modification, namely, small-scale changes of weather, and climate control, where climate or long-term average characteristics of an area are changed.

Advances in climate control have been much fewer than advances in weather modifications. The use of carbon black, coal dust, and other pigments in Alaska and in Siberia to increase solar radiation absorption and extend the growing season is a concrete example of very limited climate control.

The scientific problems of climate control are immense and many. Perhaps the most important problems are our lack of knowledge of the atmosphere and the immense energies involved in its circulation. We have few measurements of the atmosphere. Soundings of upper levels are taken twice daily at widely spaced stations, but these give us little more than a fleeting glimpse at small segments of the atmosphere. More and more data will undoubtedly become available in the next decade.

In other fields it is possible to experiment on the effects of different variables. The atmosphere is not easily studied in this fashion. If we alter certain factors, we risk disastrous results, and usually we cannot make the desired alterations anyway. The earth's atmosphere is not a laboratory in which conditions can be controlled easily.

Some new techniques for studying the atmosphere have come into being during the past decade. "Dishpan" experiments, using a rotating bowl and fluids, have provided some approximation of atmospheric behavior. The fluid can be heated at the edge and cooled in the center, corresponding to equatorial heating and polar cooling. The interior surface can be changed to illustrate the effect of changes of the earth's surface. The amount which can be learned from this type of atmospheric analog is limited, however.

A more promising approach is the mathematical analog. There are certain laws which govern motion, temperature, water vapor content, and other characteristics of the atmosphere. If we can also specify mathematically the incoming heat, the shape of the earth's surface, the present state of the atmosphere, etc., we should be able to predict the atmosphere's future behavior. In addition, we could also go

back and determine what would have happened if certain things had been changed, for example, the heat absorbed by the earth at the poles or important modifications of world geography.

There has also been much interest in improved weather forecasting. Advances in this art are closely related to an increasing understanding of the atmosphere and therefore to our ability to control the climate. For example, steps are now being taken to create a nationwide weather radar system with the cooperation of the Weather Bureau, the Air Force, and the Federal Aviation Agency. Such a system will provide much new and needed information. When sufficient knowledge is acquired regarding how the atmosphere will react to certain changes, we shall still have the problem of instituting the changes.

The energy of the atmosphere is so large that methods of climate control involving brute force by direct expenditure of man's sources of energy (fossil fuels, atomic fuels, etc.) are almost surely out of the question. Two examples should suffice to at least indicate the order of the energies involved. The energy of a large hurricane (which covers only a tiny fraction of the earth's surface) is equivalent to almost a million years of the present electrical consumption by the United States. It was recently estimated that the equivalent of the output of 12 Hoover dams is required just to keep the air over Los Angeles moving at 9 miles per hour.[8]

The use of atomic energy for small-scale weather modification has been mentioned and may be feasible for this purpose. For larger scale climate control it is less likely to be successful. There exists the possibility that small energy sources can be used to trigger larger atmospheric actions. Much more knowledge is needed, however, to determine when and where to employ this energy for best results.

The advances in the relevant sciences in the past two decades have been so startling and rapid that it may be very misleading to assume that climate control will not take place or to assume that it could only occur very far in the future. We simply cannot know how feasible it will be until we begin to understand the mechanisms of the circulation of energy in the atmosphere and in the oceans.[9]

*2. Significance of climate control for foreign policy*

The achievement of climate control will depend in part on scientific cooperation among many nations. This in itself is a worthwhile precedent for the further cooperation that will be needed once climate control is achieved. The International Geophysical Year has shown one avenue to international scientific cooperation. Could a world climate scientific effort be followed by world cooperation in climate control?

The future foreign policy problems arising from large-scale climate control would be most difficult to handle. It could be that one nation could create a desert elsewhere. How would international control be assured? For example, if a nation were in a position to improve its own climate at the expense of another nation, would this be aggression,

[8] M. Neiburger, "Weather Modification and Smog," Science, 126 (Oct. 4, 1947), pp. 637–645.

[9] See also: N. A. Phillips, "The General Circulation of the Atmosphere," Quarterly Journal of the Royal Meteorological Society, 82, pp. 123–164. J. Smagorinsky, "On the Numerical Integration of the Primitive Equations of Motion for Barodinin Flow in a Closed Region," Monthly Weather Review, 86 (December 1953), pp. 457–466. Y. Mintz, "Design of Some Numerical General Circulation Experiments," Bulletin of Research Council of Israel, 7G (October 1958), pp. 67–114. H. Wexler, "Modifying Weather on a Large Scale," Science, 128 (Oct. 31, 1958), pp. 1059–1063. Interim Report of the Committee on Meteorology, "Research and Education in Meteorology," National Academy of Sciences, Jan. 25, 1958.

or simply the natural and lawful redistribution of the resources of the planet? If one nation were able to control the climate of other areas (simply because the physical trigger mechanisms were located within its borders), and the affected nations were not able to do so, would there be a means to insure that the climate improvements would not be established at the expense of the latter nations? And finally, if one nation were able to achieve climate control before the others, would use of this ability be deterred by present legal rules or military systems?

It is easy to see that the military, legal, economic, and psychological impact of climate control would be tremendous. If the controls were exercised by national governments, mechanisms for international supervision would be comparable in complexity to the mechanisms needed to control military aggression. Indeed, even international aggression would be hard to define as a result of advances in climate control. Thus it would seem reasonable that the United States seek (1) to provide the means of rapidly advancing the basic science of the atmosphere; (2) to use its influence to have such research conducted on an international cooperative basis, or by international agencies; and (3) to study the means for achieving international control of climate-modifying procedures.

### D. THE OCEAN

In recent years, oceanography has received a great deal of attention. One reason for this is that the ocean has an important impact on world climate. To understand the factors controlling the atmosphere, a much better understanding of the effect of water movements and of transfers of energy between the boundary of sea and air is needed. A second reason is the potential wealth of the oceans and the fact that a new oceanic technology may provide new foods and mineral resources to mankind. A third and very important reason is military.

Technological and scientific advances now permit us to consider more realistically the possibility of exploration and exploitation of vast ocean resources. Among these the possibility of developing revolutionary new techniques in the maritime and submarine arts opens wide vistas. For example, with nuclear energy new marine developments are feasible that use high-energy input, operate for long periods without refueling, and have the ability to operate the propulsion machinery without oxygen. Other developments with new engines and new ship designs may greatly change marine transportation technology, particularly the uses of submarines for nonmilitary activities. Recent studies [10] indicate the possibility of using nuclear-propelled ships for high-speed submersed cargo carriers hooked one to the other like a train for intransit gathering and processing of foods, for mining and dredging mineral deposits at least in shallow waters, for laying pipelines and submersible stations, and for establishing new oceanographic research stations.

The Reynolds Metals Co. has already announced plans to build an aluminum, battery-operated research submarine, and the Navy's ordnance test station is studying the possibility for a research submarine capable of submerging to a depth of 7 miles. The U.S.S.R. is reported

[10] USAEC Contract No. AT 04-3-115 (10), "Unusual Applications of Nuclear Energy in the Field of Marine Activities, Status Report of Phase I," Stanford Research Institute, March 1959.

to have already converted a submarine for underwater research which will have viewing ports and cameras for work down to approximately 3 miles.[11] The U.S. Navy Hydrographic Office has evolved a new technique of navigation involving matching bottom topography by precision echo sounders. As a result, new bottom maps of selected parts of the oceans will start to become available.

These activities, and many others, create a new climate of interest in the wealth of the oceans. Enormous potential resources are available in the oceans, which cover 71 percent of the surface of the earth. We are aware that sea water contains practically inexhaustible amounts of dissolved salts. On the coastal shelves are extensive mineral deposits such as ilmenite, magnetite, monazite, rutile, garnet, diamond, zircon, and quartz. The sea bottom is known to have extensive manganese and phosphate deposits in the form of nodules which it may be possible to collect economically. Near the surface of the sea live enormous populations of marine organisms—potential new foods for mankind, some of which are well known, some practically unstudied.

It is with a clear awareness of the importance of the oceans and of the dangers inherent in not advancing our knowledge of oceanography as fast as that of other nations that the Committee on Oceanography of the National Academy of Sciences in a recent report, among other recommendations, stated that as a minimum—

> The U.S. Government should expand its support of the marine sciences at a rate which will result in at least a doubling of basic research activity during the next 10 years. * * *
>
> Efforts aimed at fostering international cooperation in the marine sciences should be sponsored by the Department of State, the International Cooperation Administration, and the National Science Foundation.[12]

*One example: Mining the ocean floor*

For all practical purposes we know very little about the location and size of mineral deposits on the bottom of the ocean floor. There is little doubt that submarine exploratory vessels will locate new mineral wealth. In the coming years, partially as a result of military and strategic considerations, partially as a result of developments in submarines, and particularly in atomic submarine technology, we will be in a better position to assess some of these resources.

Of significance is the recent renewed interest in the existence of manganese dioxide nodules on the floor of large areas of the world's oceans. While these were first identified about 85 years ago when the British oceanographic vessel, the *Challenger*, dredged some from the ocean floor, they have been practically ignored until very recently.[13]

A number of engineering schemes, all involving considerable capital outlay, have been proposed, but at present mining companies do not consider such ventures economically sound. However, it is probable that a pilot-mining effort will be made within 5 years, either by a group of corporations or by an enterprising government. The state of technology is already such that no insurmountable engineering problems will be faced, although the investment will be considerable. With proper backing, the effort should be a technical success within a few

[11] Business Week, Mar. 21, 1959, p. 162.

[12] "Oceanography 1960–1970," a report of the Committee on Oceanography of the National Academy of Sciences, Washington, February 1959, pp. 9 and 11.

[13] See John L. Mero, "The Mining and Processing of Deep-Sea Manganese Nodules," Institute of Marine Resources, Berkeley, University of California. Jan. 1, 1959.

years from its inception. After technical feasibility is demonstrated, it may be possible to reach economical levels of cost, and if so the number of ventures will multiply. It should be cautioned, however, that sufficient basic knowledge about the location and extent of manganese nodules is presently not available and that such information will be critical to the developmental steps outlined. Nevertheless, some educated guesses place the wealth of manganese on the ocean floor at very high amounts.[14]

The international legal and political problems arising from large-scale mining of the ocean floor are bound to be numerous in the foreseeable future. It would seem desirable to seek to establish some form of international cooperation and understanding from the outset.

### E. CONCLUSIONS

In coming decades developments in science and technology will increasingly necessitate higher levels of cooperation and understanding between nations. This will be due to the fact that such developments—

Affect universal human interests, and their impacts often cannot be contained within national boundaries;

Permit man to control or exploit resources whose national identity is not or cannot easily be defined;

Provide new avenues for international cooperation and in the absence of cooperation inevitably increase the degree of tension and friction between nations;

In some instances provide new weapons and new subtle means of international aggression.

The examples selected for this discussion, such as atmospheric pollution, climate control, and mining the bottom of the ocean, are not by any means the only areas where man's scientific exploration increases the need for real and tangible means of cooperation between nations. Quite evidently, the effect of science on ways of waging war, the advances in communication, the advances in the techniques of persuasion, the increasing trade interdependence between nations, the increasing worldwide aspirations of man to use science and technology to permit him to live creatively, these and other forces, directly or indirectly attributable to science, or at least strengthened by science, create new needs for international cooperation.

In those areas where the state of the art is still at its early beginnings, the opportunities for cooperation are perhaps greater than in areas where achievements have already been used by nations for specific policy aims. In the Antarctic, the oceans, in space, and in the atmosphere there exist new opportunities for international cooperation if the opportunities are deliberately sought. It might

[14] In his report on the economics of mining and processing deep-sea manganese nodules, John L. Mero calculates that the average grade of material dredged from all over the world is 20 percent manganese, 15 percent iron, and 0.5 percent nickel, cobalt, and copper. Some grades as high as 45 percent manganese, 1 percent cobalt, 1.4 percent nickel, and 1.8 percent copper have been reported. The reduction of the manganese is not expected to present many difficulties, and the nodules could be mined either by deep-sea drag dredging or deep-sea hydraulic dredging. With such methods the cost of recovery of the nodules would lead to low ($3 to $5 per ton) mining costs. From all the information available at present, Mero estimates that recoverable nodules amount to 45 billion tons in the Atlantic, 41.4 billion tons in the Indian Ocean, and 112 billion tons in the Pacific Ocean. In a recent article (Wall Street Journal, Jan. 26, 1959), the possibilities of recovering the manganese had reportedly aroused interest on the part of several American corporations.

be possible to achieve some degree of international understanding or even internationalization of these potential areas of conflict before things have gone so far as to create the type of problems which make international cooperation difficult. At present these are new areas of man's activity where international control could be established without necessarily impairing or reducing existing levels of national sovereignty. In so doing, nations would convert new opportunities for aggression and tension into new opportunities for international cooperation.

## CHAPTER 3

# POPULATION, FOOD, AND SCIENCE

A rapidly increasing population within a finite world creates long-range and short-range problems for foreign policy. In some parts of the world, food shortages and population pressures are already contributing to conditions that can lead to social unrest and war. This chapter examines the contributions that science and technology may make to the solution of these problems.

### A. POPULATION PRESSURES

In the last few years there has been a sudden, radical spurt in the rate of world population growth. As shown in table I and chart 7, the rate has been accelerating for a long time, but the increase in this rate during the 5 years 1950–55 was greater than the increase in the 50 years 1900–50.

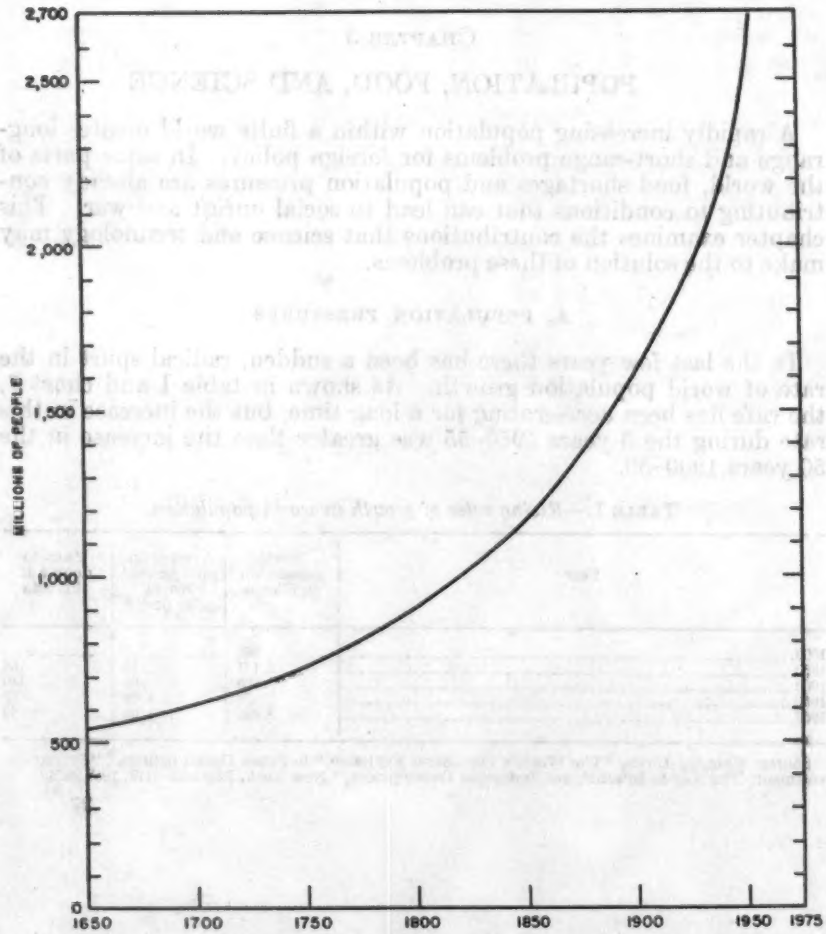
TABLE I.—*Rising rates of growth in world population*

| Year | World population (millions) | Average annual percent rise in prior period | Years to double at this rate |
|---|---|---|---|
| 1800 | 906 | | |
| 1850 | 1,171 | .53 | 135 |
| 1900 | 1,608 | .64 | 110 |
| 1950 | 2,476 | 1.04 | 67 |
| 1955 | 2,691 | 1.68 | 42 |

Source: Kingsley Davis, "The World's Population Explosion," in James Daniel (edition), "Private Investment: The Key to International Industrial Development," New York, McGraw-Hill, 1958, p. 18.

CHART 7

WORLD POPULATION, 1650 - 1955




SOURCE: W. S. and E. S. Woytinsky, World Population and Production, New York, Twentieth Century Fund, 1953, p. 34. United Nations Demographic Yearbook, 1956.

The most comprehensive analysis of future world population growth has been undertaken by the United Nations Bureau of Social Affairs. The latest estimates, based on medium assumptions concerning future trends in birth and death rates, are shown in table II.

TABLE II.—*Estimated population, and population projected by the medium assumption, of continents and the world, 1900, 1925, 1950, 1975, and 2000*

[Millions]

| Year | World [1] | Africa | Northern America [2] | Latin America [3] | Asia [4] | Europe, including U.S.S.R. | Oceania |
|---|---|---|---|---|---|---|---|
| 1900 | 1,550 | 120 | 81 | 63 | 857 | 423 | 6 |
| 1925 | 1,907 | 147 | 126 | 99 | 1,020 | 505 | 10 |
| 1950 | 2,497 | 199 | 168 | 163 | 1,380 | 574 | 13 |
| 1975 | 3,828 | 303 | 240 | 303 | 2,210 | 751 | 21 |
| 2000 | 6,267 | 517 | 312 | 592 | 3,870 | 947 | 29 |

[1] Sum of figures rounded to the nearest million.
[2] America north of Mexico.
[3] America south of the United States.
[4] Excluding the Asiatic part of the U.S.S.R.

Source: "The Future Growth of World Population," United Nations Department of Economic and Social Affairs, New York, 1958, p. 23.

These estimates indicate that world population may increase by 53 percent between 1950 and 1975, and by 64 percent between 1975 and 2000, thus doubling in less than 50 years. During 1950–75, the population of Latin America may increase by 86 percent, Asia by 60 percent, Oceania by 59 percent, Africa by 52 percent, Northern America by 43 percent, and Europe (including the U.S.S.R.) by 31 percent.

The causes of the growth in world population during the last several centuries are many. Among them are the opening for settlement of sparsely populated lands in the Americas and elsewhere, improved transportation, the progress in agriculture and industry, the expansion of trade, more effective preservation of public order, and—especially in the 20th century—the spread of improved medical and public health measures.

The remarkable insecticidal properties of DDT, discovered by a Swiss chemist in 1939, led to the development of a large family of powerful new chemical and biological weapons against disease-carrying insects. Equally important have been the advances in the social technology for making use of the new weapons. For example, the Rockefeller Foundation, the World Health Organization, and national health agencies have devised and demonstrated ways to eradicate malarial mosquitoes from large areas within a few years. The sudden drop in the death rate in Ceylon after 1946 [15] is ascribed to such an antimalaria campaign and to other public health measures. The high birth rate remained unaffected, and an explosive increase in population growth was immediately underway. Ceylon's experience is by no means unique.

A situation truly unprecedented in human history has thus been created. It is now possible, by fairly inexpensive and simple public health techniques, to drop the death rate to low "modern" levels

[15] The death rate from malaria dramatically dropped in Ceylon from about 160 per 100,000 in 1945–46 to 88 per 100,000 in 1947–48 and 2.3 per 100,000 in 1955–56. Similarly, the general death rate dropped from about 20 per 1,000 in 1945–46 to 13.5 per 1,000 in 1947–48 to 9.8 per 1,000 in 1956. See N. K. Sarkar, "The Demography of Ceylon," Government Press, Ceylon, 1957.

without first raising the economic productivity of a "traditional" society. Whereas in the western world the population growth of modern times followed economic development, in many underdeveloped countries today a very rapid population growth is preceding economic development.

Some of the countries where population explosions are taking place are already very densely peopled. Population growth rates of 2 or 3 percent a year, quite common in underdeveloped countries now, are a heavy handicap in the struggle of these countries to provide more food, clothing, and education per person. In India, for example, the present growth rate of 2 percent means a net addition of 8 million persons each year, rising soon to 10 million each year. The additional population in each decade, assuming no change in rate, will amount to about half the present population of the United States. The capital and the organizing effort that will be absorbed merely in the effort to provide tools, houses, schools, and other facilities, as well as food and clothing, for this many more people is staggering. It makes the eagerly sought goal of raising incomes to acceptable modern levels a much more distant one, if such a goal is attainable at all without checking population growth.

If strenuous efforts to achieve economic and social advancement result in little more growth in production than is necessary to keep up with population growth, the frustration of hopes will create a poor climate for democratic government. Also, internal pressures have a way of encouraging external aggression. Population pressure was not the sole cause of Japanese military aggression in the Pacific, but it was one factor; it certainly supplied an excellent argument to the expansionists who wanted to build a Japanese "coprosperity sphere."

### B. LONG-TERM IMPLICATIONS OF WORLD POPULATION EXPLOSION

The long-term implications of these rates of growth are evident. The population-carrying capacity of the world is not infinite. Some workers have studied, in the light of existing knowledge, what the population capacity of the earth might be. Estimates vary widely. Some prepared several decades ago set the maximum world population at less than 3 billion, assuming a minimum food standard. More recent studies go as high as 5 to 17 billion. A 1952 study concluded:

> The area of the world at present cultivated could support, if fully farmed by best known methods, at least 3 billion people on an adequate nutritional standard. If the lands at present unused or inadequately used could be brought into production on the same basis, potential world population climbs over 10 billion.[16]

New advances in the sciences and technologies affecting food supply could modify these estimates, but as the authors of the United Nations studies point out, the disturbing fact is that a jump to a world population of 7 billion could take place in less than 40 years. To achieve what the 1952 study suggests would undoubtedly require a level of international cooperation and determination, a level of specialization and industry, and a level of investment for which there is no historical precedent on anything approaching this scale.

In another recent study it is estimated that to feed between 4 billion or 5 billion people on an adequate diet would require a level of agri-

[16] L. D. Stamp, as quoted more extensively by W. S. Woytinsky, "World Resources in Relation to Population," in Philip M. Hauser (edition), "Population and World Politics," Glencoe, Ill., the Free Press, 1958, p. 59.

cultural productivity almost twice the present world average, which would probably take 30 to 50 years to achieve. This study concludes that to achieve this increase would require a worldwide conscious effort and substantial increases in present levels of international aid. In fact, to bring about this increase in food production would be a major financial task, estimated speculatively by these authors at $500 billion, or between $10 billion and $15 billion a year.[17]

About two-thirds of the present world population is not well nourished; to achieve higher standards of nutrition and to feed the forecast numbers of people could require an annual increase of 2.25 percent in world food production.[18] Long-term experience to date shows that the United States has only achieved a comparable rate of increase during the period of 1934–38 to 1950–55 when the tremendous scientific and technological resources of the Nation were fully marshaled into the effort. During the same period, world food production only increased by about 0.9 percent per year.[19] In fact, in many parts of the world, food production has not kept up with population growth. In these areas people are even less well fed today than they were 20 years ago. Statistics are a dry measure of human suffering, but in Asia (excluding mainland China) per capita food production in 1957–58 was 10 percent lower than it was in 1934–38. In Latin America it was 3 percent lower, and in the world as a whole it was only 1 percent higher during the same period.[20]

Such facts have led to many pessimistic discussions of the actual long-term possibilities of achieving higher levels of living in many countries of the world. Indeed, some students of the problem have reached the conclusion that population pressures are very likely to lead to violence and war.[21]

Food is the first item in a standard of living, but there are many other goods almost as essential to man in modern society. Goods and services that used to be luxuries—like shoes, educational opportunities, and medical services—are now necessities in the more highly developed countries and are rapidly becoming so in the less developed. Deprivation of these can perhaps cause more social and political disturbance than deprivation of food, since people chronically undernourished are likely to be apathetic. The discussion in the following pages relates to problems of increasing food production and of controlling population growth where needed. This discussion should be taken as a symbol of the broader problem—namely, the need to increase the per capita availability of standard-of-living goods and services of all kinds, including industrial as well as agricultural goods.

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[17] Harrison Brown, James Bonner, and John Weir, "The Next Hundred Years," New York, Viking Press, 1957, pp. 66–67.

[18] This estimate was prepared by Political and Economic Planning (PEP) on the basis of earlier and lower United Nations population forecasts. See "World Population and Resources," a report by PEP, London, Allen and Unwin, 1955, p. xvii.

[19] Ibid., p. 46. On the other hand, in postwar years higher rates have been achieved in a number of regions, but these, to some extent, have reflected readjustment to the upheaval of the war and immediate postwar years.

[20] "The State of Food and Agriculture, 1958," Food and Agriculture Organization of the United Nations (FAO), Rome, 1958, p. 12.

[21] See, for example, the conclusions of a number of studies conducted in 1958 at Technical Military Planning Operation (TEMPO)—General Electric, Santa Barbara, Calif. In the summary report, "1970: A Challenge to Planners," the authors, in discussing the world population explosion, state: "An inevitable result of the failure of the race to meet new demands from available resources will be continued change in relationships. Much of this change will be made by military rather than peaceful methods * * *. In furtherance of their cold war aims the Communist governments of Russia and China will try continuously to exploit these conflicts" (R–58TMP–100, p. v).

## C. A FIRST LINE OF ATTACK: INCREASING WORLD SUPPLIES OF FOOD

Can science and technology help relieve the deficiencies in food production? The answer is "Yes." But the answer has been "Yes" for more than 100 years; during this period, food surpluses in some areas have been matched by widespread famines elsewhere. We should not expect any miracle from future scientific advances in food production. In fact, it is difficult to evaluate the impact of science on world food productivity because it is dependent on innumerable factors, including, among many others, what national and international policies are adopted to foster the transmission and adaptation of scientific advances to underdeveloped countries.

### *1. Cultural and ideological problems*

Probably one of the most significant advances in food production, the introduction of artificial fertilizers (as opposed to natural manures and composted organic wastes) dates from the studies and demonstrations undertaken by J. B. Lawes in England in 1843.[22] Yet 100 years later, average per acre fertilizer consumption in India was still only about 1 percent of European average consumption of fertilizer.

The problem of increasing world agricultural productivity is therefore not only a problem in the physical or biological sciences and technologies. The challenge really consists in finding ways to diffuse scientific and technological advances to the countries where food production most needs to be stepped up. This requires new breakthroughs in the theories and techniques of communication—not so much in the physical aspects of communication, though this may help, as in its social aspects—and in the social sciences and technologies dealing with customs, laws, accumulation of capital, management, land tenure, religious beliefs, etc. Prospects for advances of this sort are considered in other chapters.

#### *One example: Land tenure in Nyasaland*

For example, in Nyasaland, site of some unrest in recent months, increases in agricultural productivity are sorely needed. Yet one of the more formidable obstacles to such increases lies in tribal custom, particularly land inheritance customs. Land rights in Nyasaland descend in the female line instead of the male, and when a man marries he lives in his wife's village and ploughs his wife's land. When he dies, his daughters may inherit the land; and should his wife die, the land goes to his wife's sister, or to another feminine kin, instead of to him. Every effort by a fairly enlightened administration to train better farmers has met with difficulty. The reason is simple: The men are not particularly anxious to raise the productivity of land they do not really own; and while the women do a good deal of cultivation, they do not provide the leadership needed to establish model farms. Slowly the administration is learning how to handle the problem, trying to allocate some special land not subject to matrilineal tenure to selected men, trying to train some women. Yet it takes time. In other countries and cultures there are different customs and habits that present obstacles to adoption of modern production techniques; these must be studied and means found to cope with them.

[22] He founded the Rothamsted Experimental Station, Harpenden, Herts, England, one of the world's leading centers of agricultural research.

*2. Avenues of science: Selected examples*

What can be done to extend acreage, to use better plants and animals, to reduce disease and pest damage, to reduce waste, to find new or synthetic foods, and perhaps to achieve radical new methods of food production through better understanding of the process of photosynthesis? These are by no means all the evenues open to science, but these examples indicate the possibilities of the future.[23]

*Extending food acreage*

*Control of human and animal disease in certain areas.*—In those areas where the tsetse fly now prevents effective use of much good land, successful experiments with large-scale breeding of irradiated sterile male flies open challenging new avenues to control in future years. Various means are or will be available to wipe out malaria, hookworm, dysentery, and other tropical diseases.[24]

*Displacement of certain industrial or flavor crops.*—In another part of this report we examine technological developments which may replace such crops as cotton, rubber, coffee, tea. These replacements could open substantial land areas for other purposes, including food production.

*Breakthrough in increasing availability of irrigation water.*—Extending acreage depends in many instances on the possibility of finding or developing new sources of irrigation water. The Sudan was able to utilize much arid land when Nile water was pumped to the surrounding plateau, and in recent years we have become aware in the United States of the increasing importance of irrigation water in our Southwest. There are many research approaches to water conservation:

*Control of evaporation.*—Recent experiments indicate that thin (monomolecular) layers of cetyl alcohol on reservoirs can reduce surface evaporation by as much as 50 percent.

*Reclaimed sewage.*—Modern treatment plants can provide waste water at low costs, and already a number of U.S. industries are using such supplies.

*Saline conversion.*—Progress in this field has been relatively hopeful in recent years, although the amount of research being done is not very large.[25] The Office of Saline Water in the U.S. Department of the Interior has sponsored a research program involving expenditure of about $500,000 annually, and it recently announced a $10 million program for building experimental plants. The goal of this program is water at $1 per 1,000 gallons. While this cost is still too high for most irrigation uses, it would prove economic for certain industrial and domestic demands. It would appear that a breakthrough in this field could have repercussions in arid parts of the world. Areas that would benefit include parts of Egypt, Iraq, India, Pakistan, Ceylon,

[23] For example, soil conservation is not covered in this report. Yet this should be a matter of grave concern, as each year the world loses substantial areas as a result of overgrazing, poor farming techniques, erosion, soil exhaustion, increased salinity, etc. Scientific and technological advances in this field have been substantial, but diffusion, even in the United States, has been slow.

[24] The World Health Organization of the United Nations, various universities, research establishments, government agencies and foundations in the United States and Europe, and governments of numerous underdeveloped countries are making striking progress against tropical diseases, notably malaria and schistosomiasis. Malaria, for example, is being controlled by a multiple attack. Insecticides, already well known, are being used; new antimalarial drugs (such as chloroquin) are being found increasingly effective, and new techniques for administration are making them effective over longer periods of time. Drugs such as pentachlorophenol are being used to treat water, and thus eradicate the schistosoma worm causing schistosomiasis. New techniques and materials are also being used against various nutritional diseases throughout the world, such as the kwashiorkor disease of Africa, a children's nutritional disease similar to pellagra.

[25] See "Fresh Water From the Sea," Studies in Business and Economics, Bureau of Business and Economic Research, University of Maryland, vol. 12, No. 3 (December 1958).

Peru, Mexico, Greece, Italy, Spain, and much of North Africa, not to mention our own Southwest.[26]

It is difficult to predict what new opportunities for saline conversion might arise from the experimental work now underway under Operation Ploughshare (use of atomic explosions for peaceful purposes). The problem of evaporation is one of providing heat and providing a collector for the condensate. If atomic explosions can be used to create vast underground cavities in which water can be stored, evaporated (using atomic energy), and collected, the cost might be within reach, assuming problems of contamination do not become insurmountable.

*Farming the ocean.*—New fishing techniques, such as the recently developed efficient electrical methods of concentrating and killing fish, show great promise, particularly in large factory-type operations. Concurrent advances in fundamental studies could result in better techniques to locate and identify fisheries, and in techniques to maintain, protect, and enlarge their size and reproductive capacities.

Open sea (pelagic) fisheries, primarily for tuna, today account for only a small percentage of total catches. Many of these have been developed recently, and active exploration is continuing. The potential of these fisheries is probably considerable, as indicated by the abundance of large fish and mammals (for example, whales and squid) that in certain regions live off the smaller inhabitants of the sea. This is an area where fundamental knowledge is sorely lacking.[27] Pelagic fishing should increase significantly in the next decade, and the increase will depend on the amount of research that can be devoted to this effort.[28]

*Using better plants and animals*

The past achievements of plant and animal breeders and geneticists in raising the efficiency of agriculture are well known. New startling developments in this area could take place in coming years. This is particularly true if an increased effort were undertaken to develop plants and animals particularly suited to areas of the world where the modern use of genetics has not yet had a sufficient impact. For example, Dr. N. W. Pirie, head biochemist at Rothamsted Experimental Station in England, points out that in Ghana there are hardly any satisfactory green vegetables available for consumption, but a great many useful-looking wild plants.

> We in Europe were in much that position about 1500, and then the breeders made our modern vegetables, which the sophisticated in West Africa buy from the deep freezes of Europe. The local plants should be polyploided and selected; what took us 300 years could probably be done in 30 with a few results coming in 3.[29]

[26] No worldwide study has been made of the potential implications of such a breakthrough. For what uses is water economical at various levels of cost? What areas can be opened up at varying costs of irrigation water, and how much new land might thus be made usable?

[27] In recent years there has been much literature on the possibilities of building mechanical whales to filter and harvest plankton for human consumption. Graham has suggested we concentrate on the herring, which eat plankton and are easier to catch and consume. (See Michael Graham, "Harvest of the Seas," background paper No. 24, Wenner Gren Foundation International Symposium, "Man's Role in Changing the Face of the Earth," Princeton, 1955.) Other workers in the field have shown the possibilities of plankton, and the Rockefeller Foundation has been supporting basic research in the field at various centers of oceanographic research (see F. G. Walton Smith and Henry Chapin, "The Sun, the Sea, and Tomorrow," New York, 1954). There have also been some speculations on the possibility of using atomic energy to create an upwelling current in barren areas of the sea where no such current exists and where phosphates and other nutrients are correspondingly insufficient for sea life.

[28] Recent friction between the Russians and Canadians regarding the timing of the tuna fishing season could have been more effectively discussed and negotiated if there existed a better understanding of the mating habits of tuna. Conservation measures were recognized by the 1958 Conference on the Law of the High Seas that established the first manual of international cooperation for this purpose.

[29] Private communication, 1959.

*Plant disease and pest control*

For many years researchers have attempted to control various agricultural diseases through use of organisms harmless to plants. There have been many notable successes: Black scale, a damaging citrus pest, was controlled with the insect *Metaphyscus helvolus;* mealybug pests were controlled with an Australian lady beetle; more recently, a virus has been used to control the alfalfa caterpillar.

In recent years, researchers have been turning more and more to bacterial, fungal, and viral controls. It is expected that major advances in the field of biocontrol will come through use of these microorganisms, although there is still much to be done using larger organisms.

The great economic effect of biocontrol of diseases can be seen from one recent example: several years ago vast tracts of Canadian forests were sprayed with several different viruses from airplanes. The spruce budworm, pine sawflies, and several other devastating insect diseases were all but eradicated. Perhaps even more important, the control is expected to last over many years.

Generally, the controls and the techniques exist for biocontrol of agricultural disease, and the surface has only been scratched as far as their use is concerned. A major problem in this area, as in many others, is to provide the means to diffuse existing knowledge as well as the scientific advances now taking place.

*Food habits and nutrition.*

In many areas prevalent food habits militate against adequate diets. As one author points out:[30]

> Manioc [cassava] is a remarkable crop with high caloric yield per acre. Manioc is easy to cultivate, stores well, and is resistant to drought and to plagues such as the locusts.

He goes on to add that the production of manioc is second to that of rice in many countries.

> But from the nutritional standpoint it poses many problems. Manioc has a very low concentration of protein of low quality. Thus the occurrence of kwashiorkor[31] often seems to follow the pattern of manioc production. In many societies there exist customs, taboos that also restrain the use of available foods. In parts of Uganda, milk is thought to spread leprosy, and in many parts of the world one finds taboos related to religious, fertility, or virility rites that prohibit the consumption of foods that might complement inadequate diets.

Education is the key to improving nutritional practices. To educate people successfully for better food habits requires a good understanding of the reasons for present food habits, factors in the cultural environment related to these habits, the potential impact of suggested changes, and the means of communication needed to reach the people effectively.[32]

*New sources of food, natural or synthetic*

*Proteins.*—Proteins are present in most of the higher plants. The cereal grains contain 8 to 15 percent protein, the potatoes 4 to 8 percent, and the legumes as much as 25 to 45 percent. Except for the legumes, which are already an important source of protein in such countries as Japan, protein in other plants is not sufficiently concentrated to provide an adequate protein diet or it is sometimes not

[30] J. M. Hundley, "Nutrition Problems Associated With Food Habits and Environment," in "Proceedings of the Borden Centennial Symposium on Nutrition," New York, 1938, p. 3.
[31] A nutritional disease of children in Africa, similar to pellagra.
[32] See J. Cassel, "Social and Cultural Implications of Food and Food Habits," American Journal of Public Health, vol. 47 (1957), pp. 732-740.

assimilable by humans. The meat-eating countries solve the problem mostly by having animals assimilate the vegetable protein for man. While this approach is rewarding to taste, it is expensive, since the animal is an inefficient converter. Grazing provides 10 times less protein per acre than soybeans do. For those areas where protein is scarce, it is useful to examine other possible approaches.

The potentialities of chlorella, a microorganism, able in laboratory and pilot experiments to provide high yields of fats and proteins, have not been fully uncovered. Some very interesting work has been done in growing chlorella in sewage for use as additional nutrient for animal feed.[33] Unfortunately, the results of such research are still relatively unknown, and large-scale application in protein-poor regions has yet to be developed.[34]

Some researchers have shown that high-protein concentrate can be extracted from the leaves of higher plants or from grasses. The work indicates that protein can be concentrated efficiently in this way with relatively simple machinery.[35] In fact, several leaf protein concentrators have been built and demonstrated in recent years in England. Yet, unless a social mechanism can be created to introduce such machinery where it is needed, it will remain where it is—a curiosity to Britons, an unknown potential to areas where it could be tried, tested, and adapted to local circumstances.

*Food synthetics.*—Will science provide means to synthesize some of the basic components of human food, thus possibly greatly reducing the cost of producing food? Already limited forms of chemical food synthesis provide complementary food sources. For example, most of the vitamins are now being produced synthetically, and synthetic amino acids may soon be more generally used as food supplements. The cost of synthetic amino acids is still high, although showing possibility of continued reductions. Lysine, which cost $12 per pound in 1955, came down to slightly less than $6 early in 1959. Some industry spokesmen have predicted costs below $2 per pound by 1962–64.[36] Synthetic proteins from synthetic amino acids are still a laboratory curiosity, and the problem of converting these into a synthetic roast beef has yet to be solved, but who knows what may be achieved in coming decades? The synthesis of edible carbohydrate from other sources, such as cellulose from wood, may become promising in the future. For example, the conversion of cellulose into sugar is presently receiving attention. Present processes of this sort for producing sugar for human use are still not economical, although such processes are now used to provide feed for cattle.

*A possible breakthrough: Photosynthesis.*—Advances in our understanding of the processes of photosynthesis[37] itself could have tremendous international implications. Man might be able to develop synthetic plants far more efficient than natural plants. If

[33] See Harold B. Gotaas and William Oswald, "Utilization of Solar Energy for Waste Reclamation" Edwin F. Carpenter (edition), "Transactions of the Conference on the Use of Solar Energy", Tucson, Ariz., University of Arizona, 1958, vol. IV, pp. 95–114.

[34] There has been renewed interest in chlorella for submarine and spaceship travel. The potentialities in this field were highlighted in 1953 when Constantin Sorokin and Jack Myers developed a new strain of chlorella, a thermophilic chlorella with growth properties 100 times above those of ordinary chlorella. See C. Sorokin and J. Myers, "A High Temperature Strain of Chlorella," Science, 117 (1953) pp. 330–331.

[35] N. W. Pirie, Jr., "World Hunger as a Biochemical Problem," Journal of the Royal Society of Arts, 46 (June 1958) pp. 511–528.

[36] See Chemical and Engineering News, April 20, 1959, p. 25.

[37] Photosynthesis is the natural synthesis which produces carbohydrates and oxygen from carbon dioxide and water under sunlight.

improvements of the order of 10 or 100 times were achieved, the overall social cost of providing food to mankind could be greatly reduced. While such a development may not be so important to those countries that have already achieved high levels of agricultural productivity, it could mean new opportunities to underdeveloped countries, new opportunities to devote a more substantial part of their manpower to the task of industrial development. Photosynthesis is known to be one of the most efficient photochemical reactions; in the laboratory, efficiencies of light utilization of about 25 percent can be obtained. Yet in nature the efficiency of photosynthesis is much lower. It varies from a high of 3 percent in an Iowa cornfield to less than 0.1 percent in a pine forest.

Unfortunately, we still do not understand the photosynthesis reaction at a molecular level. A good deal of work is being put into this problem all over the world, and it is quite possible that we are close to the point of being able to solve it. It may then become possible to remove the slow and inefficient steps in natural photosynthesis and replace them with more efficient ones.

*Temporary measures*

The Food and Agriculture Organization of the United Nations has studied the feasibility of establishing within the framework of the United Nations a world food reserve to help relieve famines and shortages and to counteract excessive price fluctuations.[38] Senate Resolution 85 [39] in 1955 proposed that the United States negotiate for the creation of a world food bank. No concrete developments have followed these proposals, but the United States has participated in the creation of a five-nation committee to consider joint measures for disposal of wheat surpluses without disturbing international commercial markets.[40] American food surpluses could probably be used more effectively to achieve the foreign policy objectives of the Nation if their handling was specifically planned as an instrument for promoting development.[41]

In this context, the Chinese Communist claims of increased food production bear watching. If the Chinese can achieve substantial surpluses, as they claim they will, China could not only enter the international market but achieve a psychological victory that would undoubtedly have important political consequences.

Science and technology can provide sufficient food for the existing world population, and presumably for some increases in population, although for each level of world science and technology there is a maximum population that can be fed. Food surpluses can be used as a temporary measure to provide the time necessary to diffuse modern scientific knowledge and technology to the less productive countries and to increase agricultural productivity still further. Research can be pushed in directions that may lead to unconventional methods of food production. Such a program requires new advances in many fields of science, capped by progress in the sciences and techniques that relate to diffusion and social adaptation, to permit effective

[38] See "Functions of a World Food Reserve—Scope and Limitations," FAO, Rome, 1956, and "National Food Reserve Policies in Underdeveloped Countries," FAO, Rome, 1958.
[39] 84th Cong., 1st sess., S. Res. 85, Washington, March 1955.
[40] New York Times, May 6, 1959.
[41] See the recent National Planning Association report recommending that the present surplus disposal program be revamped as a food for development program, which could be looked upon as a part of the Nation's foreign aid program rather than a disposal operation. "Farm Surpluses and Foreign Aid," National Planning Association, Washington, July 1959.

communication between those who have science and technology and those who need it. This is an area where the United States is in a position to exert leadership.

### D. A SECOND LINE OF ATTACK: POPULATION CONTROL

In certain parts of the world, population control is already a necessity. This is true in Japan, Java, Barbados, Puerto Rico, and Mauritius, all of which are overpopulated islands. It is true in Egypt, India, and China, already densely populated. It is to some degree true in many other underdeveloped countries where the task of achieving higher levels of living in the face of rapid population increase requires substantial effort and capital investment just to stand still. We all remember the words of the Queen to Alice:

> Now here, you see, it takes all the running you can do to keep in the same place. If you want to get somewhere else you must run at least twice as fast as that.

Population pressures have already led certain nations to initiate national birth-control programs. Having to select between an ultimate increase in the death rate, or a reduction in birth rates, these Governments have selected the second alternative. Puerto Rico as early as 1938, Japan in 1949, and India in 1951 instituted birth-control programs.[42]

These efforts have used what can be defined as the conventional birth-control technology (abortion clinics, sterilization, education in use of conventional contraceptive methods, etc.).[43] Japan was able between 1948 and 1956 to reduce the birth rate from 33.7 per 1,000 population to 18.5, while Puerto Rico was able to reduce it from 42.4 in 1947 to 34 in 1956.[44] The Indian program is too small and too recent to have yet brought results.

#### 1. *Cultural and ideological problems*

The problem of achieving effective birth control depends on cultural or ideological attitudes and on the availability of technical means.

The effectiveness of the Japanese birth-control program has been based on the widespread use of abortion clinics. This effectiveness reflects the fact that abortion is culturally acceptable to Japanese society, that Japan has the trained medical profession to establish such clinics, and that the geographical and population dispersion problems in Japan are not insurmountable. Yet abortion clinics are not the answer in many other countries, particularly those where abortion is not acceptable for cultural and religious reasons, and those that do not have the medical facilities needed. In Puerto Rico, sterilization

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[42] Communist China a few years ago launched a birth-control campaign, though subsequently this campaign appears to have been soft-pedaled; the ideological position is apparently still the one maintained by orthodox Communists; namely, that under socialism, production is so efficient that population growth presents no problem.

[43] Modern methods of contraception appear to have come into fairly widespread use in Europe and America in the first half of the 19th century, but their most rapid spread was after 1877. In that year Charles Bradlaugh and Mrs. Annie Besant were tried in an English court for selling a pamphlet originally issued in 1832 by an American physician, Dr. Charles Knowlton, "The Fruits of Philosophy; or, the Private Companion of Young Married People." The wide publicity of the trial enormously increased the sale of this and similar tracts, and stimulated an extraordinary demand for contraceptives. The Malthusian League, which aimed to combat poverty by encouraging birth control, was formed in England in the year of the trial, and similar organizations appeared in many countries in the next few decades. The arrest in 1914 at New York of a public nurse, Margaret Sanger, and later of her husband, for distributing her pamphlet on family limitation gave publicity to the issue in the United States, and the National Birth Control League dates from 1914–15. Mrs. Sanger toured the world early in the 1920's, arousing considerable discussion in countries such as Japan, China, and India.

[44] The decline in the birth rate in Puerto Rico is also due in part to heavy migration, which probably reduced the number of women of child-bearing age.

has been widely used, but sterilization is costly, requires medical sophistication, and its effects cannot easily be undone. Other conventional approaches that have been tested have usually not been successful, particularly in the areas where poor and uneducated people must be reached.

The worldwide consequences of the population problem are greatly complicated by the diverging cultural, ideological, and religious attitudes in many countries. In fact, as pointed out in a recent issue of the United Nations *Population Bulletin*,[45] any multilateral approach to population problems has not been possible within the United Nations because of a "three-way split in thinking concerning policy formulation" between the Communist countries, the predominantly Roman Catholic countries, and those countries where Victorian taboos make the subject matter undesirable political or social publicity.

But if we disregard for a moment the cultural and ideological problems, what of the possibility of more effective technical means for birth control? This could be highly significant, particularly in countries with low literacy and difficult communications problems.

*2. Avenues of science*

Many scientists concerned with these problems believe that an inexpensive, easily used contraceptive with limited time effect and no adverse health effects could provide the means for effectively controlling population growth in those countries where national birth-control policies are adopted.

The most promising approach at present is the development of an oral contraceptive for women, based on the ovulation-inhibiting effects of certain steroids.[46] The 1956–57 Puerto Rico tests undertaken jointly by the Worcester Foundation for Experimental Biology of Worcester, Mass., and the Family Planning Association of Puerto Rico showed that in a sample of 265 married women from a low income development project, 100 percent birth control was achieved as long as medication was kept up (i.e., taking one tablet a day during most of the menstrual cycle). Nevertheless, during the 16 months of investigation, 19 pregnancies took place, 5 of which were in women having omitted 3 to 17 tablets from the advised regimen, and 14 in individuals who had stopped medication because of reactions or "carelessness." Even with this limitation, the tests were apparently a definite success.[47] To date no serious ill effects had been suffered by the participants. Following this, Dr. Gregory Pincus, head of the Worcester Foundation, was to initiate a second test in 1959 in Bombay State in India.

The present limiting factors of this oral contraceptive are the relatively high costs of the tablets (amounting to $11 a month, although there might be appreciable reduction if mass produced), and the fact that the requirements of one tablet a day are to some extent more exacting than other conventional techniques.

Some other compounds have been tested on animals, and these tests have indicated other possible approaches. For example, some

[45] Population Bulletin, New York, United Nations, March 1959, p. 34.

[46] There are several possible research approaches to birth control. First, either the male or female may offer control mechanisms. With the female cycle, it is possible to control birth before conception and after conception. The research done to date has mostly been on the female cycle, and mostly on preconception controls, although interesting results have recently been published on postconception controls.

[47] Gregory Pincus, John Rock, Celso-Ramon Garcia, Edris Rice Wray, Manuel Paniagua, Iris Rodriguez, "Fertility Control With Oral Medication," American Journal of Obstetrics and Gynecology, vol. 75 (June 1958), pp. 1333–1346.

of these compounds can cause the reabsorption of the fertilized ova in rats and dogs;[48] others act in ways similar to the steroids.

It is doubtful that birth-control compounds could be widely applicable in Catholic countries, particularly any compound that controls birth after the beginning of pregnancy. On the other hand, in those cultural milieus where abortion is acceptable (particularly China and Japan) these latter compounds should permit (once developed) much more effective, less dangerous, and less expensive birth-control programs.

Since the Catholic Church does approve, to a limited extent, of the rhythm method,[49] some searchers have sought to devise techniques that would at least permit clear definition of monthly fertile periods. For example, it would seem reasonable that an efficient rhythm birth control might be provided by a compound that would cause a slight ill effect during the short monthly fertile period, making marital relations at least undesirable. Such a compound has yet to be found, although workers have reported tests that permit identification of the fertile period.[50]

### E. ISSUES FOR AMERICAN POLICY

World hunger and population control present major long-term international policy problems to the United States and to the other nations of the world.

In a finite world some means of controlling population growth are inescapable. The traditional means have been disease, famine, and war. If other means are to be substituted, conscious national and international policies will be required.

Population pressures can become significant causes of social unrest and war. In certain parts of the world overpopulation is already prevalent, and new approaches to the problem are urgently required. While some $30 billion are spent each year on the worldwide attack on mortality, only a few million dollars are allocated to programs which affect birth rates.[51] A possible approach would be for the U.S. Government to study (with the governments of other nations, through the United Nations, or bilaterally) the possibility of providing research funds to certain foreign agencies and laboratories (for example, in Japan and in India) for the large-scale human testing of devices, which is so necessary but difficult to conduct without adequate cooperation and funds. In this way those governments and peoples that feel the problem to be acute would be enabled to speed up their quest for the physical, biological, and social knowledge needed to check population growth by means other than disease, famine, and war.

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[48] See, for example, S. J. Segal and W. O. Nelson, "An Orally Active Compound with Antifertility Effects in Rats," in "Proceedings of the Society for Experimental Biology and Medicine," vol. 98 (1958), pp. 431–436.

[49] The church approves of the rhythm method when medical, eugenic, economic, or social reasons require birth control.

[50] For a broad discussion of social and biological problems of population control, see Richard L. Meier, "Modern Science and the Human Fertility Problem," New York, 1959. Recent scientific developments as of the end of 1958 are described on pp. 248–250.

[51] Population Bulletin, op. cit., p. 35.

## Chapter 4

# SCIENCE AND UNDERDEVELOPED COUNTRIES

**It is the policy of the United States * * * to aid the efforts of the peoples of economically underdeveloped areas to develop their resources and improve their working and living conditions by encouraging the exchange of technical knowledge and skills and the flow of investment capital * * * [for] * * * raising standards of living, creating new sources of wealth, increasing productivity and expanding purchasing power.**

This policy was formally declared by Congress and the President in the Act for International Development of 1950 and has been repeatedly reaffirmed.[52]

The problem of economic and social development is widely regarded as second in international importance only to the problem of peace and security itself, and success or failure in relation to it will have a considerable influence on the chances of maintaining peace and security. The problem is one which scientific developments have had a substantial part in creating, and one which further scientific developments may help to meet.

### A. UNEVEN SPREAD OF SCIENCE AND TECHNOLOGY

The very wide gap between the level of material well-being of the economically advanced countries and the grinding poverty of the economically underdeveloped countries reflects the uneven diffusion of modern science and technology over the world.

A good index of the extent to which a society has been able to take advantage of the productive power inherent in modern science and technology is its use of inanimate forms of energy. Chart 8 portrays the enormous range in per capita energy consumption, from the high level in North America down to the very low level in many countries of Asia and Africa. It has been estimated that an average man working 48 hours a week for a year exerts an amount of physical energy roughly equivalent to 150 kilowatt-hours of electricity. In the United States, the consumption of energy from inanimate sources represents approximately 84 times this amount for each man, woman, and child. In effect, each American has 84 synthetic slaves working for him. The average person in India has only one such slave, in Turkey four, in Ethiopia one-tenth of a slave.

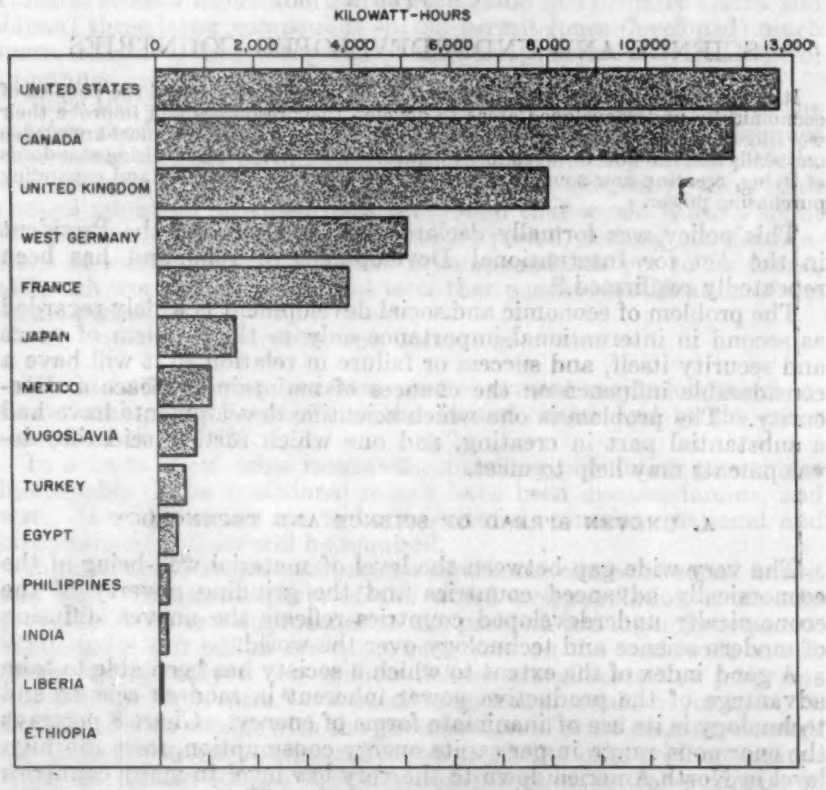
Not only is there a tremendous gap in living levels between underdeveloped and highly developed countries, but the gap seems to be widening rather than narrowing. According to the statistical services of the United Nations, rates of economic progress in the highly developed countries continue to be more rapid, on the whole, than in the underdeveloped countries, though some of the latter are now successfully accelerating their economic growth trends.

Another sobering thought is that, despite all the vaunted progress of modern times, there are probably more poverty-stricken people in

[52] The quotation is from sec. 301 of the Mutual Security Act of 1954, as amended, currently in force.

CHART 8

PER CAPITA CONSUMPTION OF ENERGY FROM INANIMATE SOURCES,
Selected Countries, 1954




SOURCE: United Nations, World Energy Supplies, 1951-54 Statistical Papers Series J, No. 2, New York, 1957, pp. 35-47. Coal equivalents given in the source have been converted to electricity equivalents at the rate of 0.6 metric tons of coal for 1000 kwh.

the world today than there were 50 or 100 years ago. This is because economic advancement has been slow or nonexistent in most of the underdeveloped countries, while their populations have been growing. Thus today two-thirds of the people of the world live in countries usually classified as underdeveloped.

*1. The revolution of rising expectations*

Of course, poverty and the lack of opportunity for self-development that it implies have been the lot of ordinary people in most of these countries for centuries. Poverty is not new. But there is a new factor. This is the awareness of poverty, the realization that it is not the inevitable lot of man, and the determination to do something about it.

This new awareness, often referred to as the revolution of rising expectations, has come about largely as an indirect consequence of modern science and technology. First, the wealth-producing capacity of

science and technology was demonstrated in the more developed countries, proving that dire poverty for the masses is not inevitable. Second, the greatly improved means of world travel and communication brought this demonstration to the attention of increasing numbers of people in the less developed countries.

The result has been a social movement imperceptibly started in colonial days by the contacts of soldiers, administrators, traders, and missionaries and rapidly accelerated by the increase in communications and education, by the social upheavals of two World Wars, and by the winning of independence in many former colonies. This vast movement can be characterized as a quest for change in man's affairs by large sectors of the world population who previously had lived within static social patterns. This accelerated transition and transformation causes many strains and pressures throughout the social organism; dealing with these strains and pressures often requires the utmost wisdom.

The world in which we live is a world divided not merely into two camps—ours and that of the Communists—it is also a world divided into other camps, such as the traditional and the modern, the rich and the poor, the hungry and the satiated, the illiterate and the educated, the free and the oppressed. Potentially the most tremendous social force in the world of the 1960's will be the people who know they no longer have to be hungry and poor, who want education and freedom, who want bicycles, refrigerators, movies, and radios, who want to see the city, who want what science and technology have made possible in the West, and who want it now.[53] This force, this revolution in expectations, may prove to be the principal modern impact of science on man—the impact on his ways of thought and on his values.

*2. Scientific advances which will make the problem more urgent*

Some of the scientific advances of the next decade will make the development problem still more urgent. Further improvements can be expected in facilities for international communication. These will tend to speed up and intensify the worldwide flow of information and ideas, by way of travel, letters, books and periodicals, films, radio, television, and tape recordings or other means of reproducing sounds and sights. Within underdeveloped countries, communication will also improve as a result of the further spread of existing technical means like roads, newspapers, movies, and the radio. There may be new developments such as much less expensive radio or possibly even television, receivers for use in every village of Asia and Africa, or new methods of education making use of electronic devices or other technical aids together with better understanding of the psychology and of the needs of diverse cultures. In consequence, the revolution of rising expectations will be accelerated and demands for development will become still more insistent.

If attempts to speed up development meet with frustration, or if it appears that the Communist countries, such as Communist China,

[53] In a recent book presenting findings from 4 years of field research by the Bureau of Applied Social Research at Columbia and the Center for International Studies at MIT, Daniel Lerner provides an illuminating human commentary on the impact and significance of this force on thousands of people interviewed in six countries of the Middle East. Particularly notable is the lack of regret, the absence among those who are in transition to modern ways of any desire to retain the old traditions. See Daniel Lerner and Lucille W. Pevsner, "The Passing of Traditional Society; Modernizing the Middle East," Glencoe, Ill., The Free Press, 1958.

are much more successful in bringing about development than the non-Communist countries, the world political repercussions could be serious indeed.

### B. CAN SCIENCE HELP MEET THE DEVELOPMENT PROBLEM IN TIME?

One of the most important issues of the next decades will be: Can the gap between rich nations and poor nations, no longer tolerable in a world of close communication and interdependence, be progressively narrowed by constructive, evolutionary means which level upward rather than downward?

If the answer is negative, the alternative might be a series of revolutionary struggles in which poor nations would become alined against rich ones in struggles that would probably involve the Communist and the Western Power blocs and make nuclear war more likely. In a world of widening gaps between poor and rich nations, the discontents of the poor would eagerly be played upon by skilled political forces dedicated to the overthrow of freedoms we value highly. No purely military strategy could cope with such a combined economic-political-military threat.

Can economic and social development be speeded up enough to bring real improvement and hope to poorer nations and to rescue the world from the threat of a calamitous political drift?

*1. Historical analogy*

Some encouragement can be taken from the fact that the Western nations have successfully met a similar issue internally during the last hundred years, with substantial help from scientific developments.

A hundred years ago the social issues that had arisen in the wake of the industrial revolution led Marx and Engels to forecast in "The Communist Manifesto" that capitalist societies would more and more split "into two great hostile camps"—in one the rich owners of capital, in the other the poor workers or proletariat. The rich would grow fewer and richer, the poor more numerous and more miserable. This polarization of society would lead to proletarian revolution.

The reality, however, has been quite different from the forecast. Within the economically advanced countries, instead of the rich growing richer and the poor poorer, an outstanding social fact has been the rise of broad, middle-income groups. No proletarian revolutions of the type Marx foresaw have occurred in the advanced capitalist countries, and only in underdeveloped countries have Communist revolutionaries been able to seize power.[54]

What defeated Marx's confident forecast about the inevitable course of events within the industrially advanced countries? There were many factors, including the effects of representative government in bringing reforms through the ballot box, reforms which often tended toward more even distribution of wealth. But certainly one of the most important factors of all was the enormous increase in wealth-producing capacity which came from the progress of science and technology in the last half of the 19th century and the first half of the 20th century. This made it possible in the economically advanced countries to achieve a very substantial rise in income levels for the masses.

Can science and technology similarly contribute today to the solution of the problem of poor countries versus rich countries by raising

[54] Except for certain areas within the Soviet military sphere, like Czechoslovakia and East Germany

the productive capacities and the incomes of all, but especially of the poor countries? No one will doubt that the answer is yes, given the necessary social and political decisions to make effective use of the potentials of science and technology. Social and political decisions, not science and technology in themselves, may be the controlling factors.

Let us assume that the necessary social and political will to make use of the means available does manifest itself in the underdeveloped countries and in the United States and other countries able to assist. What are some of the contributions that might be expected from scientific developments in the next 10 years that would help to get the job done?

*2. Contributions from the physical and biological sciences*

New developments in desalting of water, in use of solar energy and nuclear energy, in improving the breeds of plants and animals, in exploiting ocean resources, in controlling population growth, and in controlling weather and climate could make it easier to raise levels of living in underdeveloped countries. In fact, nearly every scientific development discussed in this report might contribute directly or indirectly to this end.

*3. Contributions by adaptive invention*

When techniques are carried from one culture to another, especially when they move from a country which is Western and highly industrialized to one which is non-Western and little industrialized, some element of added invention—adaptive invention—is almost always required.

The agricultural experiment stations find that they must select or develop different plant and animal varieties for different regions of the United States, and this is even more necessary when the task is to improve the varieties in different regions of the world. Fertilizers and methods of cultivation which are best in one place are not necessarily best in another, because of different soils, different climates, different skills, and different relative costs of labor, capital, and materials. Machines used to process fruits in California are not immediately useful in Iran, because of different growing, harvesting, and marketing practices.

Different relative costs of labor, capital, machines, and materials, as well as differences in management and labor skills and different needs, objectives, and philosophies, make adaptive inventions necessary. Factory methods that are more labor-intensive and less capital-using than those developed in the economically advanced countries are likely to make the most efficient use of the resources of underdeveloped countries. This requires somewhat different combinations of machines and in some cases different machine designs.

Adjustments obviously have to be made in social techniques like marketing, the organization and operation of central banks, methods of teaching reading, or methods of operating democratic government, when these are transferred from one culture to another. At least they should be made, though there have been too many cases of attempts to transfer social techniques without sufficient consideration of needed adaptations.

Most modern research and development has been directed toward the problems of the highly industrialized countries. These countries

also happen to be in the temperate zone. It is quite likely that in the next decade one of the most fruitful types of research and development will be that which starts with the large reservoir of existing science and technology and produces adaptive inventions suited to specific conditions in underdeveloped countries. This will also mean giving more attention to tropical conditions.

Simple but useful adaptive inventions [55] can be quite important in speeding the progress of underdeveloped countries. How many of them will be made, and how extensively they will be diffused when made, depends in part upon the level of effort devoted to them in advanced countries like the United States and in aid programs sponsored by the advanced countries and by international agencies. It probably depends even more upon the creation of suitable research, development, and extension institutions in the underdeveloped countries themselves, and additional support to the fair number that already exist.

*4. Contributions from the psychological and social sciences*

*Techniques of diffusion*

The underdeveloped countries can meet many of their problems by taking over known applications of science and technology, with some adaptions, but the real bottlenecks are the social tasks of innovation and diffusion. Progress in the pertinent social techniques is more important for underdeveloped countries in the immediate future than is the development of completely new physical and biological techniques.

For example, while a low-cost method of desalting sea water or brackish water for irrigation and other purposes would be very helpful in some underdeveloped countries, there are right now many areas where known techniques of well drilling and runoff storage would bring great benefit, but these techniques are not being used. Again, scientific breakthroughs with respect to some of the tropical diseases for which no good control is now known will be helpful, but public health experts in southeast Asia and similar areas point out that probably the most beneficial health measure of all would be the construction and habitual use of sanitary latrines. This requires no scientific or technological breakthrough, but an enormous task of education and change in customs.

The social tasks of innovation and diffusion are not simple tasks by any means, especially in conditions of poverty and illiteracy where there are shortages of trained manpower, of experienced administrators and managers, and of capital, and where social customs may be very resistant to change. Advances in the scientific understanding of the social processes involved in the introduction and diffusion of

[55] The Pan American Union in 1955 developed a simple mechanical press, operated by two men, which compresses a mixture of earth and a stabilizer such as cement or lime into a strong building block. For millennia bricks have been made by hand, but this device speeds up the work without requiring expensive capital investment and gives a better product at less cost. The IBEC Housing Corp. has undertaken world distribution and licensing of this simple housebuilding tool, which may become the means of significant betterment in the living conditions of millions of people in underdeveloped countries (Economic World, June 1959, p. 3).

The Rockefeller Foundation has supported much agricultural research in Latin America, including the development in Mexico of hybrid corn suited to the special conditions of regions in that country.

The Ford Foundation recently helped demonstrate in India a bullock-powered irrigation pump many times more efficient than traditional devices for raising water, and also a bullock-powered electric generator capable of providing electricity for lights and for small power tools in isolated villages.

The use of methane gas from organic farm wastes as a source of energy has been demonstrated in India, in Kenya, and in energy-poor villages elsewhere in Asia and Africa. In addition to providing gas for light and power, this technique may improve the compost and fertilizer value of the waste. (See East African Farmer and Planter, vol. 2, Nos. 5 and 6 (February and March 1959).)

new knowledge and techniques could be, in the coming decade, among the most important contributions to meeting the development problem.

For some time a major enterprise among rural sociologists in the United States has been the study of adoption of improved agricultural methods. What has been learned in Iowa about communicating information on hybrid corn to farmers and about the factors that affect their decisions to try it or not to try it cannot, of course, be carried over immediately to such different cultural environments as those of India or Peru. But some of the basic understanding and some of the techniques of research can be. To the extent that this is done in the next decade, the results will further improve understanding of the social processes involved and become the basis for better procedures in technical assistance.

Improved knowledge of the ways in which ideas and practices take hold and spread in different cultural environments will assist not only in agriculture but also in industry, transportation, commerce, education, and other fields. "Productivity centers" and similar organizations designed to encourage adoption of better industrial techniques have been established in many countries in the last decade, often with help from American development funds. Comparative studies of their operations and results, along with comparative studies of the operations of agricultural extension services and community development projects, are likely to result in stepping up the effectiveness of such efforts. Studies are underway, and more are needed, on the social skills required in rendering technical assistance. These may lead to better methods of selecting technical assistance personnel, fewer personnel failures, and more efficient use of development funds.

*Guidance of the development process*

Accomplishment of the tasks of development depends on stimulation and guidance of social processes such as effective communication of new ideas, mass and specialized education, modification of the traditional cultural framework, adoption of new habits in saving and investment, introduction of new financial institutions and practices, development of entrepreneurship, improvement of business management, and improvement of governmental organization and administration. Important decisions must continually be made about the best allocation of the scarce resources available for promoting development. Progress in the psychological and social sciences bearing on these important matters will assist materially during the coming decade in better handling of development problems.

Economists have for some years been devoting increasing attention to economic growth and development. Quantitative studies of economic development in past cases are gradually accumulating, and these will permit more reliable and detailed comparisons and advance the understanding of key growth processes. Much is being learned about the social and political prerequisites to sustained economic growth. We may be on the verge of important breakthroughs in the application of mathematical programing techniques and interindustry analysis, or other techniques employed in operations research, to the complex problem of determining the best uses for limited development funds, including the best sequence in which to develop various industries. More understanding is being gained of the role of government

and of private initiative in different cultures and in different stages of development. Research on development methods suitable for small industry and small business is going forward, as is exploration of the social origins and motivations of entrepreneurs. New knowledge is being acquired about the financial and monetary problems of development, about the development of a skilled labor force and manpower planning, about managerial development, and about labor-management relations as they appear in newly industrializing countries.

Current sociological research on the functioning of small groups and on administrative and bureaucratic organizations is likely to contribute to better understanding of important aspects of the problems that arise in development, and to more effective development methods. The role of cities in economic development and problems of urbanization in newly developing countries are being studied. Progress may be expected in the very important field of possible techniques for encouraging industrial decentralization and a socially desirable combination of rural and industrial development. Perhaps some social inventions may result which will be effective in checking the tendency to excessive concentration in large central cities. Population studies and practical experiments in control of population growth are likely to yield important new knowledge during the decade.

In the field of political science and government, most current ideas about the proper techniques by which to set up and run a democratic political system come from experience in Western cultures. Some of these ideas have been transplanted to newly independent countries of Asia and Africa, where the cultural environment is very different. The results have not always been good. In some cases (India, for example) political systems based on Western models have provided reasonably well functioning, responsible government able to carry on development tasks. In other cases the attempt has not worked out satisfactorily. The result has been ineffectual government, unable to plan or execute a development program, chronic internal strife, resort to military dictatorship, or threatened or actual takeover by the Communists. Political scientists in the coming decade will very likely give considerable attention to analysis of these experiences. Such studies, reinforced by the insights and the techniques of the cultural anthropologists and sociologists, could lead to a better understanding of the problems, difficulties, and possibilities in the introduction of modern government into traditional societies. They might provide a basis for social inventions that would assist newly independent nations or those still to acquire independence—for example, in Africa—to make better progress toward the twin goals of material well-being and political freedom.

### C. THE NEED FOR A NEW IMPETUS IN DEVELOPMENT

This is a finite world in which resources are limited. Populations are growing rapidly at the same time that new means of communication are hastening the spread of aspirations for modern levels of well-being. Political leaders in many newly awakening countries are pressed to hold out hopes and make promises that, if not quite infinite, are nevertheless going to be hard to fulfill within the limits of visible possibilities. The United States, as Congress and the President have

repeatedly recognized, has a vital stake in encouraging the economic and social development of the hitherto underdeveloped countries in freedom and peace. Competing ideologies, especially that of the Communists, insistently offer these countries alternative systems of development, without freedom and with serious implications for the world power balance.

While prospective scientific developments described in this chapter and elsewhere in the report offer hope of significant advances that will help to meet the development problem, some of the advances will also make the problem more urgent. It is our considered conclusion that the present outlook is for more rapid increase in the urgency of the problem than in the means of meeting it.

In these circumstances, some new and powerful impetus is needed to assist the development of the countries that prefer the ways of freedom. Where can this new impetus be found? Partly it could come from a new and more positive, creative use of science and technology. Discoveries and inventions particularly suited to the problems of underdeveloped countries could be deliberately sought. Scientific work designed to advance the understanding of the social processes of development and to improve the techniques of development could be speeded up. Whether these things will be done or not depends on social and political decisions; so far as science and technology are concerned, the potentiality is there. Additional effort in areas where breakthroughs would contribute to the solution of development problems could pay off handsomely, in terms of the well-being and security of the underdeveloped countries and of the United States.

## Chapter 5

# ENERGY, MATERIALS, AND TRADE

The increasing dependence of the United States on certain imported raw materials and energy resources has been one of the forces which has shaped the Nation's foreign policy and accelerated America's awareness of its interdependence with other nations.

In 1957, the United States imported 17.9 percent of its petroleum requirements, 24.5 percent of its iron ore requirements, 78.8 percent of its bauxite, 62 percent of its lead, 100 percent of its tin, 61.9 percent of its zinc, 88.9 percent of its antimony, 84.3 percent of its cobalt. The United States also imported 85 percent of its manganese ore and ferromanganese, 93 percent of chrome ore and ferrochromium, 63.6 percent of tungsten, 93 percent of beryllium, nearly 100 percent of its columbium and tantalum ores, and about 50 percent of its zirconium.[56]

These needs and the increasing complexities of our technology indicate that raw material and energy imports will continue to increase instead of decrease.[57]

The resources of the world are finite, and thoughtful persons have been concerned about the availability of sufficient raw materials and energy, once all countries of the world achieve high levels of consumption. Will new scientific advances and technology provide the means to supply the tremendous needs of the future? Attempting to answer this question, and attempting to foresee the advances of science, Dr. Harrison Brown, geochemist, wrote that man could ultimately maintain civilization with sea water, air, ordinary rock, sedimentary deposits of limestone, phosphate rock, and sunlight to supply his needs.[58]

This may very well be true, but such a process will require a considerable amount of social and economic adjustment as certain energy and raw material supplies get exhausted or become obsolete as a result of scientific advances. In fact, some of the complex problems created by the inevitable social and economic adjustments to a changing pattern of raw material and energy supplies are already with us. In the coming decades, as the United States and other countries of the world find new means of providing their increasing raw material and energy needs, and as synthetics replace commodities important in world trade, it will be necessary to establish the social technology needed to adjust to the disruptions caused by the shifts in raw material and energy requirements.

### A. ENERGY AND FOREIGN RELATIONS

In recent years, the movement of energy in international commodity trade has been principally in the form of petroleum, although coal

[56] U.S. Department of Commerce, "Contribution of Imports to U.S. Raw Material Supplies," World Trade Information Service, pt. 3, No. 58-30, 1957.

[57] The President's Materials Policy Commission in its report of 1952 forecast that for the period from 1952 to 1975 "* * * we shall more and more be following a trend that Europe knows well and that began for us in earnest a decade ago, of importing large quantities of materials which, in total, may reach from a sixth to a quarter of all we use." The President's Materials Policy Commission, "Resources for Freedom," vol. I, June 1952, p. 23.

[58] Harrison Brown, "The Challenge of Man's Future," New York, Viking Press, 1954, p. 218.

trade, particularly from the United States to Europe, has become significant in the last few years. The dependence of Europe on Middle East oil has been one of the principal factors controlling the approach of the United States and NATO countries to problems of the Middle East. The hope has often been voiced that scientific developments may in time relieve the dependence of industrial countries on petroleum sources of energy. It is important to analyze whether and when this will take place.

*1. Nuclear energy*

When nuclear fission energy was first discussed, hope was expressed that this form of energy would permit energy-short countries to develop rapidly. But in nonindustrialized areas, nuclear powerplants are not turning out to be a simple way of providing energy [59]—at least not immediately. The early optimism was somewhat abated when the implications of the complex technologies were studied in the light of the conditions in many of these countries. In many instances, conventional energy sources were found better capable of solving immediate problems while the technical manpower needed for nuclear power installation was being trained. Yet in time nuclear power should play an important role in energy-deficient countries.[60]

Similarly, the development of nuclear power programs in developed countries has been slowed by the economics of reactor-steamplant designs. These are gradually becoming competitive in Europe due to higher costs of conventional fuel there.[61] Undoubtedly the decision to go ahead during the 1960–70 period will depend in part on the cost reductions that may be achieved by wise programs of research and development.

New revolutionary developments may still take place. One possibility is the development of an economical and efficient thermocouple or other device capable of directly converting nuclear energy to electricity. The advances with plasma thermocouples at Los Alamos have indicated one line of approach, although present efficiencies of conversion are still very low.

Another approach may be the possibility of using underground nuclear explosions to generate power. While it is too early to evaluate the success, cost, and significance of Operation Plowshare, the possibility of such an approach is of interest. Nuclear explosions in underground liquid reservoirs may provide steam to run turbines and generators. The hazard problems will probably be the most serious challenge to this program. In any case, it is very doubtful that such developments would change the nuclear energy picture in the next 10 to 20 years.

[59] The implications of U.S. national nuclear energy policies to development of world nuclear capabilities are ably presented in National Planning Association, "Productive Uses of Nuclear Energy—Summary of Findings, Policy Suggestions for the Future," Washington, September 1957.

[60] At the Second Geneva Conference, India's Dr. Homi Bhabha expressed the confidence that his country would be able to initiate a nuclear energy construction program in the near future; as a matter of fact, India has a 250- to 1,000-megawatt program planned for 1960. Japan is already planning a 7,000-megawatt program by 1975. Elsewhere developments are slow. Conventional energy resources are available and even plants running on imported fuels are still more easily installed and operated than nuclear plants.

[61] In a recent paper, Sir Christopher Hinton, Chairman of the Central Electricity Generating Board, United Kingdom, predicted that if the present trend in United Kingdom coal costs continues, and if the development of nuclear power stations can be continued at the same pace, nuclear power will be cheaper in the United Kingdom than conventional power by 1962 or 1963. (See Sir Christopher Hinton, "Industrial Power of the Future," Journal of the Royal Society of Arts, vol. 56 (June 1958), pp. 529-543.)

*Fusion energy*

There have been many hopes regarding the feasibility of a workable thermonuclear reactor system using the hydrogen isotope deuterium of heavy water. In addition to providing a nearly inexhaustible fuel supply, such a source of energy would not present some of the contamination and waste problems of fission energy.

The control of a fusion reaction requires means of containing a plasma at extremely high temperatures. While some early achievements led to optimism, most of the experts attending the second international conference on the peaceful uses of atomic energy voiced their disappointment regarding the advances in the field.

L. K. Artsimovich, U.S.S.R.:

> We do not wish to be pessimistic about the future of our work, yet we must not underestimate the difficulties which will have to be overcome before we master thermonuclear fusion reactions.[42]

Edward Teller, United States:

> We are still very far from a successful thermonuclear machine * * * today we do not have enough knowledge to recognize a surprise if it came * * * economic exploitation of controlled thermonuclear reactions may not turn out to be possible before the end of the 20th century.[43]

Sir John Cockcroft, United Kingdom:

> * * * the important question is whether we can maintain stability in our plasmas as we feed in more and more energy and whether we can, in due course, reach the breakeven point where energy generated by fusion equals the energy input.[44]

At the present time, the more optimistic of those in the field feel that 10 years will be required to demonstrate a workable system, others say 25, while others have lost hope. In general, the attitude is definitely more pessimistic today than it was a year ago. Yet this is another area where unpredictable new discoveries could suddenly change the picture.

*2. Solar energy*

Unconventional energy sources include, among others, solar, wind, tide, and geothermic energy. Of these, solar energy is the most important potential source of useful energy. Among a number of scientific achievements in this field are solar batteries, which permitted the Vanguard satellites to continue broadcasting long after the Sputniks had become silent.

Widespread use of solar energy requires solution of two major problems: first, inexpensive and efficient collectors; second, some means of storing energy, since solar energy is intermittent. Until these problems are solved, the applications of solar energy will be limited to those now in use or in development (solar batteries for communication equipment, high-temperature solar furnaces, solar distillers for converting saline water to drinking water, experimental solar house heaters and coolers, and solar refrigerators, not to mention the production of salt by solar evaporation).

Certain avenues of solar energy research are promising. Advances in thermoelectric or thermionic technology may in time provide sufficiently efficient means of converting solar energy directly into electric

[42] L. K. Artsimovich, "Investigations on Control of Thermonuclear Reaction in U.S.S.R.," Proceedings, Second International Conference on Peaceful Uses of Atomic Energy, vol. 31, P/2298, New York, United Nations, 1958, p. 20.
[43] Edward Teller, "Peaceful Uses of Fusion," Proceedings, ibid., P/2410.
[44] Sir John Cockcroft, "Summary of Conference," Proceedings, ibid.

energy; advances with resistant plastic films may provide inexpensive collecting surfaces for certain uses; the discovery and research on selective surfaces may provide new high-temperature collectors.[65] The conversion of solar energy to useful energy through the production of hydrogen by the photochemical breakdown of water under exposure to sunlight would provide a useful way to use and store solar energy.[66]

Finally, the possibility of using trees and other living plants as additional sources of power should not be forgotten. For example, hardly any attention has been paid to the possibilities of wood-burning engines for countries where kerosene tractors are now being used to open new land for cultivation. The kerosene is imported at high cost, while the wood is burned on the side of the clearing.

A breakthrough in the sciences of solar energy could provide a most important complementary source of energy: for sunny areas where the energy demand is not heavy, in villages and in residential districts for household uses, for cooling and refrigeration, for lighting streets or roads, for communication needs, for small industries where simplicity and low technological complexity can be important. In many parts of the world, if economic and efficient means were discovered, more solar energy could be recovered from roof tops of individual residential houses than is provided during the year through conventional sources.

Most of the American research effort in this field is now oriented toward the energy requirements of space vehicles. The U.S.S.R. has a fairly substantial program oriented toward the needs of arid regions, in addition to space programs.

At present levels of research effort, no major breakthrough permitting the widespread use of solar energy in arid or sunny regions should be expected in the coming decade. However, a stepped-up scientific research effort in this field might bring a considerable change in the outlook. Such a step-up is definitely needed.

### *3. Prospects for fossil fuels*

In all likelihood, the growing industrial needs of the world will continue to depend during the next decades on conventional fossil fuels.[67] These conditions will, therefore, place continued importance on those resources of fossil fuels (such as petroleum, and to a lesser extent gas and coal) that constitute a substantial segment of international trade.

There undoubtedly will be many advances during the coming decades that will permit increases in the efficiency of use of energy. Such developments as free piston engines, increased use of gas turbines, thermopiles, fuel cells, and new chemical batteries for automotive

[65] Solar collectors do not get very hot unless radiation is concentrated. A novel approach was taken at the Research Council of Israel to develop selective surfaces that capture the solar radiation but do not reradiate all the heat, thus achieving higher equilibrium temperature than conventional collectors. H. Tabor, "Solar Energy Collector Design," Bulletin of the Research Council of Israel, vol. 5C, No. 1 (November 1955).

[66] Some work in this field is now underway at Stanford Research Institute. The success of the research depends on the identification of suitable photocatalysts which would permit such reactions. It is still too early to know whether such photocatalysts can be identified.

[67] Water power will continue to provide a small share of the total world requirements, estimated at about 2 percent by Guyol in his recent study. Nathaniel Guyol, "The Energy Picture in 1984," Petroleum Refinery, January 1959, p. 104.

power [68] will, in time, increase the overall efficiency of energy utilization. Yet the overall trend of increase will be slow.[69]

Three potentially important developments could alter the present international petroleum picture. These include:

1. A substantial reduction in cost of exploitation of oil shale. While oil shale is rapidly becoming competitive, it is doubtful that the development of oil shale will proceed very rapidly as long as oil is plentiful and the cost differential not large.

Although experts do not predict important changes in the near future, new developments could happen sooner than expected. For example, there is some speculation about the possible use of nuclear explosions to liberate the oil from oil shale.

The oil shale reserves of the United States are considerable [70] and will undoubtedly be tapped some day. We do not know enough to say when, but this will depend in part on the level of priority accorded research and engineering development.[71]

2. Synthetic petroleum from coal. There are a number of processes already developed, but their costs are still high. Some experts in the field believe recovery of oil from shale will be achieved sooner.

3. Potential development of ocean transportation of liquefied gas, particularly between the Western Hemisphere and Europe.

Taking into account the probability of such developments, one recent estimate [72] tentatively sets world energy supplies in 1975 at nearly 40 percent from petroleum, 14 percent from natural gas, 34 percent from coal and lignite, 6 percent from nuclear, and 6 percent from hydro and miscellaneous sources.

International shipments of oil, now about 2½ billion barrels a year, will increase to more than 4 billion barrels by 1965, close to half the 9 billion anticipated as total demand in the non-Communist countries.[73] These estimates foresee that total U.S. imports of crude oil and refined products will triple by 1975. Table III shows these estimates in greater detail. These figures assume a growing importance for petroleum as an energy resource in the foreseeable future.

[68] While there is interest in developing new batteries for automotive power, it appears more likely that if and when piston engines are replaced, the trend will be toward fuel cells or thermopiles still probably requiring hydrocarbon fuels, at least in the immediate future.

[69] Putnam, in his well-known study of world energy requirements, estimates an overall increase of U.S. total energy efficiency from about 30 percent in 1950, to 43 percent in 2050. Palmer C. Putnam, "Energy in the Future," New York, Van Nostrand, 1953, p. 105.

[70] The U.S. oil shale proved reserves in the Green River formation are estimated (December 1957) by the U.S. Geological Survey at 1.1 trillion barrels equivalent (assuming 75 percent rock recovery). This is about 4 times world reserves of petroleum.

[71] See Charles H. Prien and John W. Savage, "A Shale Oil Industry Is on Its Way," Chemical Engineering Progress, vol. 52 (January 1956), pp. 16–5 to 21–5, and State of Colorado, Department of National Resources, "Location Patterns of Shale Processing—Shale Oil Refining Industrial Complexes," September 1957.

[72] Nathaniel Guyol, "The Role of Petroleum in World Energy Supplies." The 1959 Fifth World Petroleum Congress, sec. 9, paper 4, New York, May 31–June 5, 1959.

[73] Assuming a net flow of crude oil from Communist to non-Communist nations, although the total is assumed to be a small percentage of total international movement (less than 2 percent). These assumptions bear watching, since the Soviet Union may well adopt policies to increase oil flows for political or trade purposes. Some estimates place Russia's surplus oil production for 1970 at about one-third of Western Europe's needs. (See P. Maitland, "Russia in the Raw Materials Market," The Director, London, November 1958, p. 285.)

TABLE III.—*Estimated crude oil reserves, production, and demand in non-Communist nations* [1]

[Millions of barrels]

| | Reserves, December 1958 | Production | | Demand | |
|---|---|---|---|---|---|
| | | 1957 | 1975 | 1957 | 1975 |
| Total Eastern Hemisphere (Europe, Middle East, Africa, and Far East) | 180,000 | 1,570 | 5,820 | 1,702 | 5,710 |
| Total Western Hemisphere (except United States) | 25,340 | 1,445 | 3,970 | 825 | 2,350 |
| United States | 35,650 | 2,914 | 4,750 | 3,219 | 6,550 |
| Total non-Communist nations | 250,030 | 5,929 | 14,540 | 5,746 | 14,610 |

[1] Total annual discoveries of crude oil in the United States have exceeded annual production in 20 out of the last 22 years. This relationship is expected to continue until some time in the 1975–85 period, resulting in a reserve level of 40 to 45 million barrels at that time.

The apparent imbalance between free world demand and production is accounted for by inventory changes, natural gas liquid production outside the United States and Canada, and net imports from the Soviet bloc.

Reserves and production for the United States and Canada include natural gas liquids.

Source: Estimated by Stanford Research Institute.

## B. SCIENTIFIC DEVELOPMENTS, RAW MATERIALS, AND WORLD TRADE

Scientific developments and technological advances continually create new demands for existing or new raw materials. The sudden importance of uranium and thorium may be taken as an example. The increasing importance of the high-temperature metals such as columbium, tantalum, molybdenum, tungsten, and chromium results mostly from new demands.

### *1. America's increasing dependence on foreign resources*

The most authoritative attempt at foreseeing future U.S. raw material needs in relation to those of the rest of the world was undertaken more than 7 years ago by the President's Materials Policy Commission. This Commission, headed by William S. Paley, worked from January 1951 to June 1952, and the resulting report had an important impact on subsequent American raw material import policies.[74] The report stressed America's continued dependence on imports and went on to urge that the United States take the necessary steps to remove the potential barriers that could limit availability of future supplies of raw materials. The Commission recommended that approaches to stabilize world raw material markets be made through international buffer stocks and other commodity agreements, and at the same time made a plea for new technological innovations to—

Bring into use materials which are not presently used;

Apply more generally the principles of recycling of raw materials;

Learn how to deal with low ore concentrations;

Develop and use more economically those resources that cannot be renewed;

Lessen or eliminate need for scarce materials.

It appears today that the overall trends foreseen by the Paley Commission will not be greatly altered by prospective scientific develop-

[74] The Paley report considered the materials requirements of the United States and Canada plus those of Western Europe and Japan. No attempt was made to forecast the materials requirements of the newly industrializing countries, partially because of the lack of data and other difficulties involved, partially because the Commission assumed the changes in demand from these countries would not alter the general conclusions of the study.

ments. The Commission's estimates have with the passage of time proved to be too conservative, so that in certain fields America's dependence on imported raw materials will be substantially higher than foreseen.

*2. Development of synthetics*

Scientific advances in the future will undoubtedly create new demands for certain raw materials not now in great use. Similarly, the continued search for synthetics may displace certain commodities. While the overall impact of these displacements may not greatly alter the total volume of world trade, it may have serious consequences for the international trade of particular regions and countries. In fact, the obsolescence or displacement of important commodities in world trade may well be one of the most difficult foreign policy problems to be faced by the United States and by other nations in the coming decades.

*The case of rubber*

During the first World War, the Germans worked on synthetic rubber, producing about 2,400 tons of methyl rubber. These experiments were abandoned when natural rubber was again available. In the thirties, work was resumed, and by the beginning of the Second World War synthetic rubber had been produced in both Germany and the Soviet Union in substantial amounts, while some pilot plants had been built in the United States. In 1942, synthetic rubber represented only 2.8 percent of U.S. rubber consumption. The rapid program initiated under war pressures resulted in its increase to 57.9 percent of total consumption by 1946. Immediately after the war the importance of synthetic rubber went down somewhat but then climbed slowly to 53.5 percent of total U.S. consumption by 1957.[75] Natural rubber continued to compete with synthetic in many applications where butyl, neoprene, or other synthetics did not have the necessary physical characteristics.

In addition, the rapid postwar expansion of the automotive industry in Europe and America provided a heavy demand for both natural and synthetic rubber. World production of natural rubber continued to rise in the postwar period. Yet in 1958, when demand slackened, world natural-rubber production dropped by 16 percent compared with 1957, while synthetic only dropped by 5 percent.

In March of 1959, Shell Chemical Co. and United States Rubber Co. revealed plans for commercializing a synthetic "natural" rubber, almost identical with tree-grown rubber. The announced selling price of this "isoprene" rubber was 30 cents per pound, which would place it in competition with natural-rubber prices.[76]

Other companies have also been working on synthetic "natural" rubbers. Goodrich has been experimenting with its own Ameripos SN, developed in 1954, and has it in pilot plant stage. Phillips is working on "Cis-4" and Goodyear, on Natsyn. In addition, several companies have developed "super" synthetics; that is, synthetics with characteristics that natural rubber cannot match for specific applications.[77]

[75] See discussion on synthetic rubber, Percy W. Bidwell, "Raw Materials, A Study of American Policy," New York, Harper, 1958, pp. 246–283.

[76] See Chemical and Engineering News, March 21, 1959.

[77] For example, polyurethane tires, capable of lasting almost as ong as the automobile itself, are being improved to withstand high-speed driving.

It may be too early to predict what impact these true synthetics will have on natural rubber. Natural-rubber costs can probably be reduced further, and can continue to compete with the synthetics, at least in the immediate future. But it becomes apparent that synthetics will be very powerful competitors in U.S. markets and increasingly so in Europe and other areas.

Other developments affecting the use of rubber could further alter the picture. Will a hovering or skimming craft ultimately replace the wheeled vehicle? Probably not in the coming decade, but possibly within 50 years?

Developments affecting the future of natural rubber obviously merit close study and policy attention. The impact on the economy of a number of Southeast Asian countries could be disastrous.

*Synthetic fibers*

In 1957, synthetic fibers [78] had captured, in dollar terms, 28 percent of the U.S. textile fiber market, mostly at the expense of other fibers.

The competitive strength of synthetic fibers is evidenced by the rapid reduction in per capita consumption of natural fibers. U.S. per capita consumption of wool went from 4.3 pounds in 1950 to 2.2 pounds in 1957; cotton from 31 pounds in 1950 to 24 pounds in 1957; and flax from 0.07 pound in 1950 to 0.04 pound in 1957. In the same period, U.S. per capita consumption of synthetic fibers jumped from 0.92 pound to 3.3 pounds.[79]

The competitive position of synthetics may be further improved as new fibers, such as low-pressure polyethylene and polypropylene, may provide sufficient quality at low price to invade new nonapparel markets. Within apparel markets, present research efforts are directed at reducing synthetic fiber costs and improving quality. For example, treatment of synthetics to introduce artificial crimp into filaments, in imitation of natural fibers, permits the production of stretchable knitted synthetic fabrics which appear to have considerable consumer appeal.

What will the outlook be for natural fibers such as cotton, wool, and jute? At present it does not appear that they will be completely displaced, and it is still possible that research may provide new means to improve natural fibers. Improved natural fibers might then compete advantageously, or continue to be used in combination with synthetics. But the level of effort in synthetic fiber research promises many startling changes in coming years, and it is not impossible that within 10 to 20 years wool and cotton could be very effectively challenged, perhaps even displaced, by newer synthetic fibers. Such developments would obviously have a serious impact on the economies of cotton-growing areas in this country and abroad and on the economies of wool exporters.

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[78] Synthetic fibers include acrylic and acrylic-type, acrylonitrilestyrene, dinitrile, polyamide, polyester, polyethylene, polypropylene, polystyrene, polyvinyl acetate, polyvinyl alcohol, polyvinyl chloride, polyvinylidene, chloride, protein, TFE-fluorocarbon, vinyl chloride acetate, and glass fibers. All except glass fibers are organic chemical products. Synthetics are presently higher priced than natural fibers, but special qualities, such as greater strength and rot resistance, enable them to compete with natural fibers.

[79] Synthetic fibers are usually considerably lighter than displaced fibers. For example, in tire cord 0.6 pound of nylon can replace 1 pound of rayon; and in marine rope, 1 pound of nylon can replace 4 to 9 pounds of manila. Total per capita consumption of fiber, partially as a result of this, has dropped from 45 pounds in 1950 to 36 pounds in 1957. (See Stanford Research Institute, Chemical Economics Handbook, vol. 5, table 542.521.)

*Synthetic weaving or sheet textiles*

But the future may hold still more scientific and technological breakthroughs. Instead of spinning and weaving, it may be possible to create a fabric by a process that bypasses expensive intermediary steps. For some time a number of laboratories have been attempting to create synthetic textiles that need no weaving but have some of the characteristics of woven material.

Such sheet textiles could conceivably result in very low-cost fabrics that would not only affect the natural fiber producers but also the spinning and weaving industries. Such developments may take place in the next 10 or 20 years. If they do, this could mean major economic and social readjustments in many regions of the world where the production of textiles and fibers plays an important role.

*Synthetic or substitute coffee*

In the last 10 years, the growth in sales of soluble coffee ("instant" coffee) in the United States has spurred the search for the identity of the flavor compounds lost in the dehydration process. The unique coffee flavors of the better grades of coffee are caused by a combination of many compounds. If the compounds lost in processing could be identified, they could be replaced in the soluble coffee, thus improving its flavor.

Furthermore, if all or most of the compounds responsible for the characteristic coffee flavor could be identified, soluble coffee could probably be produced at low cost directly, without using coffee beans at all. It would probably also be possible to identify the compounds present in different blends, and to market substitute or synthetic soluble coffee imitating, or possibly accurately reproducing, the flavor of the very best grades of natural coffee and of the most preferred coffee blends.

The possibility of identifying the compounds in coffee aroma results from the recent development of gas chromatography,[50] a technique of analysis that permits separating and identifying mixtures of aromatic chemicals weighing only millionths of an ounce.

A number of laboratories in this country and abroad are presently seeking to identify the flavor compounds present in coffee. Published research results[51] indicate that over 30 volatile compounds have been identified, and that a mixture of the components already identified gave an aroma similar to the original natural essence. The analysis, it was reported, was still not complete, but would undoubtedly be completed in coming years, if not in coming months.

When most, or even all, the compounds creating various coffee flavors are identified, thus providing knowledge of what causes the differences in aromas from different varieties of blends or roasts, there is little reason to doubt that a substitute (or even synthetic) flavor could be re-created.[52]

Once the necessary formula of flavor compounds had been achieved, it would be possible to add this to a body made from the roast of any suitable grain, such as wheat or barley. Thus it might become

[50] Coffee Brewing Institute, "Coffee Aroma Analysis by Gas Chromatography," Tech. Bull. No. 34, New York, 1959.

[51] See a brief description of these research results from two laboratories in "Chemical and Engineering News," 37 (April 20, 1959), p. 51.

[52] A substitute flavor is one imitating, but not exactly reproducing, the original. A synthetic is an exact reproduction of the original.

possible to produce at a much lower cost [83] a soluble or ground coffee probably as good as the better blends and grades from Yemen, Guatemala, or Colombia. This coffee could easily be made with or without synthetic or natural caffein.[84]

It is most probable that some such development will take place. It is not possible at present to foresee the exact time sequence. The research is already well underway, and the preliminary results reported in technical journals would indicate that it may only be a matter of a few years, or perhaps only months, before synthetic or substitute coffees are ready for the market. It is also not possible to predict the degree of consumer acceptance. However, if prices are substantially lower than natural coffee prices, as seems likely, the competitive position of substitute or synthetic coffee will be strong. It is probable that natural coffee could still compete at much lower prices, but even so a considerable reduction in foreign exchange earnings, incomes, and jobs would be felt by the coffee-exporting countries.

*Other synthetics*

It is at least reasonable to question whether tea and cocoa might not ultimately face the same type of competition as coffee, although at present there seem to be no immediate prospects of such developments. Synthetic sugar is still more expensive than the natural product—but a cost breakthrough may be possible.

Natural leather will probably not be completely replaced, but will meet increasing competition from plastics and rubber. Animal glue will be almost entirely replaced. In the protective-coatings field, the emulsion-type paints and synthetic lacquers will continue to invade the area previously held by linseed oil and natural varnish resins.

Many of the natural waxes will be replaced by synthetics, or will undergo modification. In the fats and oils markets, traditional soaps will lose still more to detergents, particularly in the toilet-bar market.

Synthetic organic medicinals, such as antibiotics, vitamins, hormones, sulfa drugs, aspirins, amino acids, are replacing natural products. Synthetic organic insecticides, synthetic dyes, and synthetic fertilizers have already taken large shares of markets previously held by natural products.

The synthesis of industrial diamonds was recently achieved, and the industry feels confident that synthetics will competitively supply half of U.S. needs within a few years. Synthetic quartz crystals are now being grown in pilot-plant operations, and much research is going into synthesizing production of high-grade mica.

Finally, reinforced plastics are vigorously entering new markets, and U.S. production is expected to treble in the next 12 years. It can be anticipated that in time these plastics will increasingly compete with metals, wood products, paper, and ceramics.

*3. Impact of synthetics on world trade*

While the overall effect of scientific developments is probably to expand international trade by increasing production and income, specific developments may at times have a devastating effect on particular commodities and on these who produce them. Countries that

[83] Chemists with expert knowledge of these problems guess that the cost might be only one-fourth or one-fifth the present cost of coffee delivered in U.S. ports.

[84] Synthetic caffein is presently produced in Germany and in the United States. Future supplies of caffein might still come from coffee beans, although it is doubtful the beans could be economically grown just to produce caffein.

depend on one or a few commodities for large portions of their export earnings are particularly vulnerable to the possible development of synthetics or substitutes. Table IV shows two principal exports of a number of such countries.

TABLE IV.—*2 principal exports of selected countries*

[As percent of total 1957 exports]

| Country | Export | Percent of total 1957 exports | Export | Percent of total 1957 exports | 2 principal exports as percent of total 1957 exports |
|---|---|---|---|---|---|
| Bolivia | Tin | 60 | Lead | 9 | 69 |
| Brazil | Coffee | 61 | Cacao | 5 | 66 |
| Burma | Rice | 73 | Cotton | 2 | 75 |
| Ceylon | Tea | 61 | Rubber | 18 | 79 |
| Chile | Copper | 67 | Nitrates | 10 | 77 |
| Colombia | Coffee | 75 | Petroleum | 14 | 89 |
| Costa Rica | Coffee | 49 | Bananas | 39 | 88 |
| Cuba | Sugar | 81 | Tobacco | 6 | 87 |
| Egypt | Cotton | 72 | Rice | 7 | 79 |
| El Salvador | Coffee | 79 | Cotton | 11 | 90 |
| Ethiopia | Coffee | 64 | Oilseeds | 9 | 73 |
| Ghana | Cacao | 62 | Wood | 12 | 74 |
| Guatemala | Coffee | 72 | Bananas | 13 | 85 |
| Haiti | Coffee | 71 | Sisal | 14 | 85 |
| India | Tea | 19 | Jute and bagging | 16 | 35 |
| Indonesia | Rubber | 36 | Petroleum | 30 | 66 |
| Israel | Citrus fruit | 36 | Diamonds | 23 | 59 |
| Malaya | Rubber | 57 | Tin | 16 | 73 |
| Mexico | Cotton | 23 | Coffee | 15 | 38 |
| New Zealand | Wool | 38 | Meat | 14 | 52 |
| Nicaragua | Cotton | 44 | Coffee | 34 | 78 |
| Pakistan | Jute | 49 | Cotton | 21 | 70 |
| Philippines | Coconut products | 40 | Sugar | 19 | 59 |
| Thailand | Rice | 48 | Rubber | 19 | 67 |
| Uruguay | Wool | 50 | Meat | 21 | 71 |
| Vietnam | Rubber | 60 | Rice | 25 | 85 |

Source: International Financial Statistics, vol. XII, No. 4 (April 1959), Washington, International Monetary Fund, pp. 26–30.

Of the 26 countries listed, at least 15 would suffer major readjustments in their economies should coffee, tea, and cacao be replaced to a considerable extent by synthetics or substitutes, and if natural rubber and wool continue to be replaced.

The impact of any such replacement depends, obviously, upon the speed and extent with which it occurs and upon the alternatives open to the producers. The replacement of Chilean natural nitrates by nitrogen fixation from the air took place gradually, over several decades, and even now Chile exports some 200 million tons annually (against 400 million before the First World War), though its share of the greatly increased world production has fallen from more than 60 percent to less than 4. Silk, which was Japan's principal export for many years, lost ground relative to rayon during the twenties and thirties, but absolute amounts exported continued to increase until the depression of the thirties; the final blow, from nylon, came just before the Second World War, and its effects were masked by the general wartime interruption of trade. Natural rubber has continued to be produced in large volume, in fact in absolutely increasing volume, despite the competition from the synthetics hitherto available. But even if volume of natural-rubber output is maintained, price pressure

from future synthetic rubber is likely to reduce the earnings of producers.

It is not yet possible to know how rapidly or slowly new synthetics might displace traded commodities. Unknown factors like the qualities of the new product, cost of production, preferences of buyers, and government controls are involved. Yet some of the possibilities described in this chapter are so important to the stability of so many countries that continued close watch of developments and forward planning to deal with possibly serious repercussions is advisable.

*One example: Possible impact of substitute coffee on Brazil*

Imports, and the foreign exchange to pay for them, are crucial to Brazil's industrial and economic growth. It is estimated that imported goods constituted on the average about a third of the goods used in gross capital formation in the period from 1945 to 1954, and in the vital sector of industrial capital formation the proportion was probably higher. Moreover, while local capital goods production is expanding quickly, the rapid growth in general industrial capacity may create requirements for machinery, equipment, and spare parts faster than local production is growing. Should this be the case, the industrial complex will be growing more dependent on imports rather than less. In any case, there is little or no evidence that the pressure for essential industrial imports is being diminished during the current phase of industrial growth. Many observers feel that import requirements may double or triple in the coming generation of rapid industrial growth.

For many years, coffee, cotton, and cacao have constituted the overwhelming proportion of Brazil's exports. Substitute coffee would have a major impact not only on the coffeegrowers, but on the entire process of economic development in Brazil, depriving the country of its most important present means of earning the foreign exchange with which to purchase needed imports—in fact, wiping out all the benefits of past U.S. aid.

A secondary impact of importance would be the immediate reduction of Brazilian purchases in the United States, causing significant losses to U.S. exporters.

It appears evident that such developments could lead to major social unrest, periling America's security, unless the necessary steps could be taken sufficiently in advance to assist Brazil in developing new exports or unless plans were made for means of providing the foreign exchange Brazil would need during the difficult period of readjustment.

It is staggering to realize that the successful development of substitute coffee could result in major economic dislocations in Brazil, Colombia, Costa Rica, El Salvador, Ethiopia, Guatemala, Haiti, and Nicaragua, not to mention minor dislocations in other Latin American and African producing nations.

*4. Synthetics and the interdependence of nations*

The trends of world trade between the industrially developed and the newly developing countries have been characterized during the last decades by a rapid growth of the import requirements of the latter, which has not been matched by a similar growth in the import requirements of the industrially developed countries. Thus, in the period 1928–57, imports of nonindustrialized countries rose by about

400 percent, while exports rose only by 300 percent.[85] Similarly, in 1928, the nonindustrial countries had an export surplus of about $1,700 million, and in 1957 they had an import surplus of about $3,400 million.[86]

Recent studies conducted by the United Nations and by GATT (General Agreement on Tariffs and Trade) indicate that the continued protection of agriculture in many of the developed countries and the expected raw materials needs of these countries will result in future patterns of growth in raw material trade at rates lower than growth of the projected foreign exchange requirements of the newly developing countries.[87]

The trend toward increased import requirements of the newly developing nations will increase if these countries can continue to industrialize within the framework of the non-Communist economy. As an example, the panel of experts appointed by GATT to study trends in international trade indicated (on the basis of simplified assumptions) that a country seeking to increase its annual rate of growth by an additional 2 percent a year would probably require as much as a 10 percent increase of imports.[88] The prospects for export earnings of most countries do not usually permit such increases, and the prospects for growth become then dependent on the net flow of investments and/or on aid. The prospects for servicing investments or for ultimate repayment of loans also depend on the increase of trade.

A recent study evaluates the prospects for U.S. imports in 1975.[89] Adopting the U.S. growth assumptions of the Paley Commission, which may be low, the study showed that the value of U.S. imports in 1975 would amount to about 2½ times that of 1948, and nearly double that of 1952. Doubling imports between 1952 and 1975 means an annual compounded rate of increase of about 3 percent. A more recent study conducted by the United Nations Economic Commission for Europe projected for the period of 1955–75 an increase in trade between the newly developing countries and Western Europe, Canada, and the United States in the range of 50 to 75 percent, about 2.8 percent per year.[90]

The possible scientific advances described in this chapter will even accentuate the inability of newly developing countries to find sufficient markets in developed countries. For example, the United Nations study still projected a 55 to 60 percent increase in coffee trade over 1955–75, but only an overall 35 to 45 percent increase in agricultural raw materials trade (already reflecting the probable impact of some but not all synthetic fiber developments). The study also projected an increase of 30 to 40 percent for foodstuffs during the same period.

These projections may be compared with the estimated increases of 75 to 140 percent for mineral fuels and 130 to 170 percent for minerals and base metals, which show the great difference existing between the prospects for trade of petroleum and metal-producing countries and the prospects of countries exporting food and agricultural raw materials.[90]

[85] GATT, "Trends in International Trade. A Report by a Panel of Experts," Geneva, October 1958, p. 26. The countries included for these comparisons do not include Soviet bloc nations.
[86] GATT, ibid., p. 27.
[87] United Nations, "Prospective Trade Structures," ch. V of "1957 Economic Survey of Europe," Geneva, 1958. GATT, op. cit.
[88] GATT, ibid., p. 50.
[89] See Henry G. Aubrey, "United States Imports and World Trade," Oxford, 1957.
[90] See United Nations, "1957 Economic Survey for Europe," op. cit., p. V-4.

### C. TRADE PROBLEMS FROM SPREAD OF MODERN PRODUCTION METHODS

The prospects are that efficient production methods based on modern science and technology will continue to spread to new countries during the next decade, probably more rapidly than in the past. Indeed, it is an important aim of the U.S. foreign policy that they should spread rapidly to countries now economically underdeveloped. The spread of improved production methods will, however, raise additional trade problems that will require policy decisions by the United States.

The adoption of modern industrial and agricultural methods in countries of Asia, Africa, and Latin America where wage levels are low will result in a succession of changes in production and trade patterns like those touched off by Japan's modernization in an earlier epoch. U.S. producers will face a combination of new competition and new market opportunities. New competition will be felt both in export markets and in the U.S. domestic market. New market opportunities will result from the expanding demand for productive equipment in the developing countries and from the increased incomes and purchasing power of these countries, if their development efforts are successful.

American producers and the Government will have two basic policy alternatives in this situation. One is defensive and restrictive. Producers could be given protection against entry of lower priced products into the American market; perhaps, by trade bargaining, efforts could even be made to exclude the new competition in some markets abroad. The other alternative is adaptive and developmental. New types of imports, including those competing with U.S. producers, could be welcomed as an inevitable feature of dynamic trade development. If adaptive adjustments are made, such a policy would benefit both consumers and producers. American producers could exert themselves to keep one step ahead of the competition, shifting out of less promising lines and into expanding ones. Among the latter will be new products and processes, equipment of types needed in development, and types of consumption goods and services which will be wanted by peoples enjoying higher income levels.

The consequences of this basic policy choice by the United States will be most important in three respects. First, it will influence the pattern and soundness of our own economic growth. Insistence upon insulating ourselves from new currents of competition instead of encouraging continual adaptation to a changing world economic environment would make the economy vulnerable to future shocks and probably retard its growth rate. Second, American refusal to accept new kinds of imports would greatly reduce the chances of successful development by methods compatible with freedom, in the underdeveloped parts of the world. Third, such a refusal would prevent repayment of loans and investments which the U.S. Government or private business may provide to developing economies abroad, for repayment can be made only if these countries can somehow earn dollars.

### D. CONCLUSIONS

It is crucial for all nations to be able to achieve economic growth in future years while maintaining approximately balanced payments with other nations. For this reason, the impact of scientific developments on the trading ability of nations is particularly significant. Also important is the net flow of foreign investments, loans, and grants, which, together with exports and miscellaneous earnings, have to close the foreign exchange gaps of newly developing countries.

It is pertinent to ask what alternatives the United States and other non-Communist countries could offer to affected underdeveloped countries if and when the coffee market, for instance, is no more. What alternatives are open to those newly developing countries whose foreign trade prospects seem insufficient? More foreign investments? More loans? More grants? New exports? Control of synthetics? Nothing?

It becomes apparent that the realities of a dynamic technological world no longer permit nations to plan their future completely independently of other nations. A nation must either plan its growth in the context of the growth of the entire world, or sooner or later find that its scientific, technological, and economic aspirations conflict with the aspirations of other nations.

It is in fact doubtful that some of the underdeveloped agricultural exporting countries can continue for long to withstand the pressures of the rapidly changing technological developments which the science and technology of the industrial west are creating. Either these countries will rapidly acquire the ability to withstand the consequences of scientific and technological change in a world market economy, or they will ultimately be forced by internal pressures to exchange the democratic heritage of the West for totalitarian solutions. Thus, it would appear that the security of the United States and Western European countries will in the very immediate future call for a reappraisal of their trade, investment, and aid policies.

Can planning and scientific research provide better guidelines for the difficult policy problems which the scientific developments described in this chapter will raise?

In recent years military planning has taken a new dimension in the United States. New interdisciplinary techniques of analysis and new concepts have provided insights into the problems inherent in maintaining the country's present posture of deterrence. We know, for example, that decisions must be planned well in advance, because a leadtime exists between the date a decision is made and the date a defense system becomes operational.

No adequate studies have been published, however, covering the total future material requirements of the world or of the non-Communist countries. But while raw material consumption increases at a slower rate than gross national product in highly developed countries, the reverse may well be true for countries at an early stage of industrialization. It will therefore be increasingly important to take into account in planning U.S. requirements the energy and raw material requirements of the underdeveloped countries. The lack of such studies and lack of information about such requirements have precluded their consideration within the scope of this study.

Similarly, there is a definite need for a tentative overall analysis, a framework, of the future patterns of world economic growth. Such analysis could provide preliminary data to answer such questions as: What new markets will Brazil be able to enter in 1970? Where will these markets be located? Can we expect our present trade policies to resist the passage of time and the consequences of economic developments in the newly developing countries? Will America price itself out of world markets? Will we have to give more consideration in our foreign policy to the utilization of the new products coming from nations no longer so underdeveloped? What will foreseeable trade shifts mean to American industry? It may also be possible to devise techniques to assess the probable effectiveness of certain policies, of certain decisions, and thus improve the possibility of planning for long-term instead of short-term objectives.

Some of these questions will increasingly come to the fore as science and technology shift and change the patterns of world trade.

## Chapter 6

# SCIENCE AND INTERNATIONAL COMMUNICATIONS

### A. DEVELOPMENTS IN THE PHYSICAL MEANS OF COMMUNICATION

Scientific developments leading to improved physical communications are bound to have important international repercussions. Three aspects are discussed here: telecommunications, international scientific communications, and communications in the less developed countries.

*1. Meeting future international telecommunications requirements*

A recent study provides preliminary estimates of future global telecommunication requirements.[91] These were prepared on the basis of such assumptions as: Limited wars and no major wars, continued world population growth, continued worldwide economic expansion, and continued military expenditures. These preliminary estimates, probably on the conservative side, indicate a doubling of normal demand for world telecommunications between 1958 and 1970. The study goes on to estimate that additional technological advances (faster airplanes, more complex systems, etc.) will once again double demand for telecommunications; and, finally, natural causes (sun spots) and human causes (more airplanes at higher altitudes, satellite interference) may bring about the equivalent of another doubling in demand. These three factors would lead to an estimated eightfold increase in traffic density. These estimates, while at best most tentative, do provide an order of magnitude worth examining.

There are several ways in which science may provide the means to handle estimated increases in the need for telecommunications. For example, developments in fields outside of telecommunications could in some cases alter the needs for telecommunications. Advances in mail delivery by rocket could reduce the volume of certain types of messages that now proceed on telecommunication channels. Advances in information theory may provide new guides on how little information must be sent to maintain intelligibility.

The development of ionospheric scatter communications makes possible a new type of long-range link employing one or more "hops" of 1,000 to 1,500 miles but requiring elaborate and expensive transmitter, receiver, and antenna installations at each relay point. These systems presently have rather stringent limitations on the volume of communications they can carry.

Tropospheric scatter systems, having capability for transmission of a much greater volume of communications over each link, can be used where the distances between stations can be kept to not more than about 500 miles. But here again, transmitter, receiver, and antenna costs at each relay point are very substantial.

[91] James E. Hacks, Jr., "Communications: The Future Natural, Technological and Social Environment of Global Communication," Report RM-68-TMP-62, TEMPO, General Electric Co., Santa Barbara, Calif.

Improvements in components, techniques, frequency prediction, methods of modulation, and other factors affecting the long-established high-frequency communications systems can be expected to substantially increase their capacity and reliability for peacetime communications.

Satellite relay systems can provide increased communications capacity over great distances. The satellites may function as passive reflectors, to bring beams back to the earth at a great distance from a transmitting station, or as active relay stations, carrying a receiver and relay transmitter. The National Aeronautics and Space Agency is pursuing an active program to develop the technology for both passive and active relay systems.

A project sponsored by the Defense Department's Advance Research Projects Agency looks to the provision of hovering equatorial repeater satellites which would provide fixed relay stations above points on the Equator. Three satellites of this type could provide relay service to most of the globe. Small areas in the vicinity of the poles would have to be covered by other means. As presently foreseeable techniques are exploited, these equatorial repeater satellites could ultimately provide the communications capacity necessary to relay television signals from continent to continent if desired.

The military has underway a considerable amount of scientific work, much of it classified, on the development of components, techniques, and methods to provide new communication systems. It is probable that in the coming decades this research will contribute heavily to providing high-capacity, lower cost systems for nonmilitary use.

The study mentioned previously [92] surveyed developments in such fields as components, modulation techniques, coded signals, pulse coding, transmission control, nonradio communications, and communications management, and concluded that if present technology were used rationally it could provide a 320-fold increase in telecommunication capability. In other words, with appropriate organization and the necessary degree of international agreement, it should be easy, technologically speaking, to handle all foreseen telecommunication requirements to 1970.

However, to date, the level of international agreement, organization, and control has not been sufficient to permit the rational utilization of existing technology. In fact, unless order is brought in, by 1970—

> it will no longer be possible to allow the freedom of choice of radio frequency we have today. Continuation of present Government policies in this area will lead not only to increased annoyance in many population segments but to actual disasters increasingly serious as time goes on.[93]

Unless unforeseen scientific developments reduce the need for international cooperation in telecommunications (and the reverse is almost certain to be true) future peaceful relations between nations will require much more effective organization, control, and cooperation.

### *2. International scientific communications*

Because of the vast volume of scientific and technical data pouring out each year, scientists and technicians throughout the world find it impossible to keep up with the work even in their own specialized fields. One of the greatest needs of our system of communications

[92] Ibid., pp. 19-27.
[93] H. Mattraw and J. W. Moyer, "Frontiers of Technology—Trends in Electronics Research," Report RM 58-TMP-63, TEMPO, General Electric Co., Santa Barbara, Dec. 31, 1958.

is to make the publishable results of scientific activities readily available to those scientists who can benefit from them.

*Information retrieval systems*

In recent years, the possibility of using information retrieval systems in conjunction with mechanical translation machines has received considerable attention in the United States, in Europe, and in the Soviet Union. However, the potential international importance of creating integrated information centers may not have received sufficient attention. The rate of advance of science in non-Communist countries will increasingly depend on the level of international communications achieved between scientists. This level will be closely related to the availability of international information retrieval systems serving these scientific communities.

*Machine translation*

With the growing universality of scientific work, the translation of foreign scientific works into English and of American works into many tongues will be a necessity if the United States scientific community is not to cut itself off from the rest of the world, thereby reducing its ability to benefit from scientific developments elsewhere.

Since 1946, when the first serious work began on mechanical translation, a great deal of effort, both in the U.S.S.R. and in the West, has gone into learning how to perform language translations automatically by means of high-speed electronic computers. Although many problems must still be solved, important advances have been made in recent months. As an illustration of the degree of facility that has been achieved, it should be noted that Russian scientific text has been translated into English at a machine processing rate of 10,000 words an hour.[94] Except for the omission of an occasional article, the amchine translation is quite readable. With minor post-translation editing, the result is, for most purposes, equal to a good human translation.

The problems of direct machine reading of alphabetical characters and the handling of graphical information are receiving attention. If these can be solved, a very inexpensive and rapid means of translation is available, at least for scientific and technical material.[95] Great strides are now being made in the development of automatic means for reading printed numbers for business applications. Limited success has also been obtained with machine-reading of alphabetical characters printed in a stylized type font, but if really cheap mechanical translation is to be possible from publications over which we have no control, means must be found for machine-reading of the printed page.

The machine capabilities for translation can be very useful both in the handling of published material and in implementing the most sophisticated search procedures of an automatic information retrieval system. If, in the process of setting type for printing technical articles, all U.S. technical journals could make a record in a machine-readable medium, such as punched paper tape, the problem of machine translation would be greatly simplified. In fact, the vast amount of information in U.S. scientific journals, estimated at 2.5 billion words annually,[96] could be translated into one foreign language by approximately 20 high-speed computing machines.[97]

[94] With faster machines, already available, rates of 50,000 words per hour could be achieved.
[95] The cost of fully automatic machine translation could be less than 5 percent of the cost of human translation.
[96] About half a million articles are published a year. The statement in the text assumes 5,000 words per article.
[97] With a computer rate of 50,000 words an hour; 200 hours per month of computer time.

*3. Communications in less developed countries*

An area's communication complex is its entire existing pattern and practice of human communication, including everything from the traditions which control such matters as who speaks first to whom, to the language itself, to the equipment of communication in its broadest sense (roads, waterways, printing plants, television transmitters), to the organizational pattern that determines subject matter and controls opinion. A country such as the United States, with a multiplicity of mass media (newspapers, radio, television, magazines, books, etc.) plus vast telecommunications and transportation networks, free-speech tradition, and an elaborate educational system, has a highly developed communication complex. Any country with problems of language and literacy, no libraries, few roads, no effective mail service, few newspapers, an inadequate telephone system, few radios, and a tradition of secrecy and keeping one's own counsel generally, has a poor communication complex.

Table V provides measures of mass communications in a selected sample of countries. A quick rundown shows ranges of illiteracy from 1 percent to 95–99 percent. Daily newspaper circulation per 1,000 inhabitants varies from slightly over 1 in Liberia to more than 600 in the United Kingdom. Availability of radio receivers per 1,000 inhabitants varies from less than 1 in Afghanistan to nearly 800 in the United States. The table indicates the very slight penetration television has made in most of the nonwestern countries of the world.

TABLE V.—*Measures of mass communications in selected countries; 1954–55*

| | Number of illiterates per 1,000 population | Daily press circulation per 1,000 population | Radio receivers per 1,000 population | TV receivers per 1,000 population |
|---|---|---|---|---|
| North America: | | | | |
| United States | 20- 30 | 344.5 | 795.6 | 219.3 |
| Canada | 20- 30 | 243.6 | 277.7 | 74.4 |
| South America: | | | | |
| Brazil | 500-550 | (1) | 44.8 | 2.2 |
| Argentina | 100-150 | 97.9 | 157.7 | 2.7 |
| Bolivia | 750-800 | 19.3 | 48.3 | ---- |
| Colombia | 450-500 | 53.7 | 41.3 | .03 |
| Peru | 550-600 | 38.7 | 55.3 | ---- |
| Africa: | | | | |
| Nigeria | 800-850 | 3.1 | 1.3 | ---- |
| Liberia | 900-950 | 1.2 | 2.0 | ---- |
| Morocco | 850-900 | 22.5 | 34.4 | .47 |
| Libya | 850-900 | 5.7 | 3.3 | ---- |
| Sudan | 900-950 | 2.3 | .68 | ---- |
| Union of South Africa | 550-600 | 56.0 | 49.7 | ---- |
| Middle East: | | | | |
| Egypt | 750-800 | 22.8 | 18.5 | ---- |
| Israel | 50-100 | 162.4 | 148.5 | ---- |
| Iraq | 850-900 | 18.7 | 12.4 | ---- |
| Iran | 850-900 | 5.9 | 8.6 | ---- |
| Saudi Arabia | 950-990 | 1.4 | 1.4 | ---- |
| Asia: | | | | |
| Afghanistan | 950-990 | 1.8 | .67 | ---- |
| India | 800-850 | 6.7 | 1.9 | ---- |
| Burma | 500-550 | 8.1 | .78 | ---- |
| Ceylon | 400-450 | 36.8 | 10.8 | ---- |
| Japan | 20- 30 | 397.9 | 129.9 | .40 |
| China (continental) | 500-550 | 13.7 | 2.6 | ---- |
| Europe: | | | | |
| United Kingdom | 10- 20 | 609.6 | 272.8 | 81.7 |
| France | 40- 50 | 239.9 | 206.6 | 2.9 |
| Denmark | 10- 20 | 370.4 | 298.9 | .54 |
| U.S.S.R. | 70-100 | 210.5 | 95.7 | 3.3 |

[1] Not available.

Source: UNESCO, "World Communications, Press, Radio, Film, Television," 3d ed., 1956.

These differences between the less advanced and the more advanced countries in indexes of mass communication are greater than the estimated differences in per capita income levels, which vary by a ratio of about 1 to 50 between the less advanced and most advanced nations.

In coming decades, the diffusion of existing or new communication technology throughout the world may be expected to accelerate. One of the major effects of this diffusion on foreign relations problems of the United States will be the acceleration of the revolution of rising expectations in underdeveloped countries, described in a preceding chapter. In fact, if present social pressures for higher levels of living are examined in the light of present rudimentary means of communication, it becomes apparent that the revolution of rising expectations is only starting. The forces that have been upsetting the traditional ways of the past will continue to increase, rapidly creating new social pressures on the governments of the underdeveloped countries to achieve visible results, and also creating additional demands for effective means of international communications.

*4. Need for policy on international communications*

Understanding between nations and peoples is the critical problem of our time, and it can be achieved only through improved communications between peoples. Peaceful international intercourse between nations and peoples is carried on by many means, including personal travel contacts, the mails, the use of international telephone systems, the telegraph, and through the mass media of the press, the radio, and television.

*International travel and personal communications*

Personal contacts abroad can appreciably change the international outlook of people and help reduce tensions. Personal contacts through travel of U.S. citizens abroad are expected to increase more rapidly in the immediate future (the jet age) than they have in the past. In 1958, nearly 1½ million Americans traveled abroad by air or by ship. By 1970, partially as a result of technological advances that are lowering travel costs, it is expected that this figure will jump to 4½ million, not including land travel to Canada and Mexico. This increased flow will have an influence on the attitudes of foreigners toward the United States. It will also have a most important influence on the attitudes of U.S. citizens toward international problems.

Quite probably the social sciences will provide in the future better tools to evaluate the impact of increasing means of personal communication on international relations. It has already been shown [98] by a sampling of highly traveled American businessmen [99] questioned on international problems that they are more internationally minded than businessmen who are not highly traveled, and are better able to adopt positions opposed to their own immediate self-interest but in line with longer-range interests.

Results of this and other research confirm the importance of personal communications in improving international understanding. In recent years many imaginative programs have been instituted to increase the flow of international travelers and to improve the constructive quality of this type of personal communication. Exchanges of scholars and students, visiting missions, international conferences and fairs already

[98] Ithiel de Sola Pool, Suzanne Keller, Raymond A. Bauer, "The Influence of Foreign Travel on Political Attitudes of American Businessmen," Public Opinion Quarterly, 20, No. 1 (spring 1956), p. 166.

[99] Businessmen who have undertaken at least 5 international trips.

play an important role. How can these very important contributions to better international understanding be further enhanced? A conscious policy to improve productive personal communication could be studied and evolved and might well include further use of funds derived from sales of United States surplus agricultural products to substantially increase the flow of representative Americans and community leaders abroad.

*Telecommunications*

The development of international telecommunications by the United States has been on a competitive, uncoordinated, at times almost anarchistic, basis. There is no central policy or planning organization charged with the promotion, encouragement, and development of international telecommunications as an aid to American foreign relations and as an instrument of American policy, as has been the case with the development of international air transport and atomic energy. The several military services have pioneered in the development and improvement of many of the techniques and systems of telecommunications, but even this has been done on a competitive, often uncoordinated, basis. The systems providing international civil telecommunications are split between a number of competing American companies, all subject to the commercial pressures of trying to remain solvent and profitable in the face of competition with each other and with airmail, while doing business with Government telecommunication monopolies in most other countries of the world.

These problems have been examined previously,[100] but present and future world conditions make their solution more pressing.

The rationalization and lowering of international press communication rates could be important in increasing the flow of international news and commentaries.[101] International press communications are an important instrument of national policy in most of the advanced nations of the world, and Tass, Reuters, and others are aided by direct or indirect subsidies in transmitting news to their newspaper readers and radio listeners in foreign countries. Of course, Tass is a direct Government operation in the U.S.S.R. and is supported by Government funds. An example of support in the Western countries is the so-called "penny press rate" through which British news is distributed over the Government-operated cable and wireless systems. Although the U.S. Information Agency transmits some news for use in foreign countries, the bulk of the American news is distributed overseas without Government assistance and at rates which run to as much as 15 to 20 cents per word for transmission to some foreign countries.

*What else might be done?*

Development of machine translation could receive further support, and the international communications needs of the scientific communities of the world could be examined. The U.S. Government could consider the merits of providing the research funds to develop small solar-powered radios for use in underdeveloped countries or to develop miniature clandestine receiving sets for use in areas where freedom of information is denied.

[100] "Telecommunications—A Program for Progress," a report by the President's Communications Policy Board, Washington, March 1951.
[101] See, for example, UNESCO, "The Problems of Transmitting Press Messages," Paris, 1950.

There are evidently many more possibilities for making use of scientific advances in the field of communications. It would seem prudent to devote attention to the entire spectrum of alternatives and to plan a rational communication development policy designed to provide the means of international communication which will be required in the future. In the last analysis it will be the Nation's ability to clarify its future policies on international communications which will determine the nature, scope, and use of the scientific and technological advances taking place in this field.

### B. DEVELOPMENTS IN THE PSYCHOLOGICAL AND SOCIAL SCIENCES RELATED TO COMMUNICATION

International problems are in many instances problems of finding common grounds on which to base effective communication. It may very well be that during the next 20 years the most important breakthroughs in world communication will result from advances in the psychological and social sciences and technologies, permitting improvement in flow of meaningful messages. A meaningful message is one that uses symbols that can be perceived by the recipient as the image, idea, or concept the sender wanted to convey. Such breakthroughs could result from increased understanding of differences and similarities in the cultural, linguistic, and behavioral patterns of individuals and groups all over the world, and of increased understanding of the mechanisms of individual and group behavior.

For example, a scientific development already well underway is the adaptation of opinion-sampling techniques to different cultural milieus. Recent work [102] clearly shows the possibilities of such techniques.

New understanding of the mechanisms of individual and group behavior may also provide new techniques to influence and orient the behavior of people. While we are still far from an overall science of human behavior, current progress in the fields of perceptual processes, learning, motivation, group behavior, cultural processes, attitudes, and opinion changes are leading to more fully validated theories. There should be little doubt that such scientific advances will increasingly find useful application in the formulation and execution of the foreign policy of the United States.

#### *1. Communication problems in technical assistance*

It is probable that in the coming decade the influence of intercultural studies by anthropologists, sociologists, and social psychologists will continue to have a profound impact on ways of thinking and on the approaches taken to important international problems. To diffuse knowledge effectively and to carry on other types of international cooperation require an appreciation of individual and group motivation which is particularly difficult to achieve with respect to quite different cultures. For example, in the course of providing technical assistance, it is not sufficient simply to explain Western concepts such as maintenance, cost accounting, and human relations or other management skills. People must be sold on using them, because they do not now fully appreciate the value of such techniques. Actually, the motiva-

[102] Such as the studies in the Middle East conducted by MIT and Columbia. See Daniel Lerner and Lucille W. Pevsner, op. cit. See also a description of American practices with respect to attitude research, as contrasted with Soviet practices, in chapter 1, Daniel Lerner (editor), "The Human Meaning of the Social Sciences," New York, Meridian Books, 1959.

tion may be more important than the explanation, because once really sold, a person often will find some way to get the specific information he needs.

It is important to recognize that motivational factors must be introduced in terms the host people can understand, not in terms of what advisers from the United States think ought to be done. To accomplish this requires knowledge of what the people in an underdeveloped country are trying to accomplish, what values are predominant in their way of life, and what means of communication are most effective. Technical advice which requires change is most successful when provided in such a way as to give confidence to the potential users. To do so requires considerable awareness of the probable cultural and social impacts of such change.

Advances in intercultural studies of motivation may be used increasingly by agencies concerned with development and the diffusion of science and technology. Such advances may be reflected in the approach taken by the United States toward development in other countries. For example, India will continue to need American help and America will continue to wish for a successful Indian development program. In the coming decade it may be more generally accepted that India can only become a new India, not a new America. As a result, it may be understood that not all American experience is meaningful to India. Outside help might then be made more effective by being given in ways that enable Indians to see that the paths offered can lead successfully to Indian goals, not merely to furtherance of U.S. goals.

In the past, technical aid has often been identified with resistance to communism, which is only one aspect of the problem from the underdeveloped country's point of view. Theirs is also a fight with increasing hunger and increasing social problems and a race with a revolution in expectations. It is probable that an important contribution of the social and psychological sciences in coming years will be to make our Government aware that the oversimplification of the problem, and our concern with communism, probably do not always motivate the underdeveloped countries to act as we hope they will. If the United States becomes able to recognize the nature of the problems of other countries and can tackle what people in these countries consider the real jobs to be done, the United States will probably communicate more effectively and achieve better results.

*2. Teaching machines*

In the last decade a number of psychologists have shown the effectiveness of immediate positive reinforcement [103] as a technique for motivating individuals to act in desired patterns, and very recently this principle has been applied in the development of teaching machines.[104]

One such machine is a simple boxlike mechanical device containing a set of questions which are displayed to the student one at a time. The questions are programed in very gradual steps that progressively teach the student to answer questions that are more and more

[103] positive reinforcement is the presentation of what has been experimentally found to be satisfying to the recipient.

[104] See B. F. Skinner, "Teaching Machines," Science, vol. 128 (Oct. 24, 1958), and B. F. Skinner, "The Technology of Education," Cumulative Record, New York, 1959, pp. 143-182. Another program of teaching-machine development is now underway at the University of Arizona. See "Teaching Machine Adapts to Student," the Christian Science Monitor, July 3, 1959.

difficult. This is made possible by a mechanism that unlocks a more difficult question only after the student has provided the correct answer to a prior question. Thus the student gets the immediate positive reinforcement of proceeding to the next question when he gives a correct answer.

An important advantage of the machine is that it keeps up with the student but does not outdistance him. In the ordinary classroom the teacher cannot adjust his pace to each student.

While the art of programing such a machine and the art of building it are at the earliest beginnings, there should be little doubt that such devices could become increasingly important classroom auxiliary teaching tools. Combined with films and television, these machines might provide the basis for a major revolution in the techniques of education, and already a number of U.S. commercial firms are examining the nature of this potential market and the possibility of developing the programs and equipment for commercial application in the United States.

In our society, and in the rest of the non-Communist world, we face a grave shortage of educators. Could the combination of teaching machines, closed circuit television, and films provide a new approach to education and to international problems of diffusion of knowledge? Closed circuit television has already proven useful.[105] One can conceive of a vast program of world education provided by a limited staff of technicians and educators going from village to village, in many countries of the world, using teaching machines and films to diffuse knowledge.

These concepts do not present unsolvable problems. To accomplish this vision, it would be necessary to study further the learning problems involved, to develop the necessary equipment, and to develop educational programs suitable for it. This would require considerable research and considerable testing and experimentation. Could the United States, preferably in cooperation with other nations of the world, consider the feasibility of such an undertaking?

*3. Psychological techniques and control of men's minds*

Much has been learned in the last 20 years about techniques of psychological warfare. It has been learned that indiscriminate use of the mass media will not influence large audiences, but they can be influenced if the values of the groups composing them can be identified. For example, propaganda has been found to be more effective when it deals with survival values than when it deals with the wrongness of moral values.

During the Korean conflict, the psychological warfare of the Chinese Communists resulted, for the first time in American history, in strange defeats for the United States in prisoners' camps. Twenty-one Americans decided to stay behind; one out of three of the 7,190 U.S. prisoners mildly collaborated with the enemy; one out of seven collaborated seriously; and 38 percent died, not so much from malnutrition or bad treatment, but from disorganization, lack of morale, lack of discipline, lack of goals, and lack of survival values.[106]

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[105] See John K. Weiss, "Teaching by Television in Hagerstown," School Review, Chicago, 1957; "The School of Tomorrow," Saturday Review, Aug. 24, 1957; and the Fund for the Advancement of Education, "A Report of the First Year (1957 and 1958) of the National Program in the Use of Television in the Public Schools," New York, January 1959.

[106] For a discussion based mainly on U.S. military reports, see Eugene Kinkead, "In Every War But One," New York, Norton, 1959.

During this period, the Communists did not submit Army prisoners to any special forms of torture, but instead submitted them to a form of "group reeducation," which had much to do with the effectiveness of the results exemplified by these figures.[107]

More recently, a young American couple who spent 4 years in Chinese prisons on charges of espionage returned to write a document which throws light on the techniques used by the Communists to achieve political and ideological conversions.[108] During 4 years, while apparently under no excessive physical violence, drugs, or hocus-pocus, but under much uncertainty and fear, the Ricketts were submitted to a continuous process of directed or forced group therapy, within a group of other prisoners, which led ultimately to what was an ideological conversion in a religious sense of the word.

The Ricketts appear to have been from average American families. They were probably not particularly Communist-oriented when they first went to China (before the Communist victory), and they were probably quite unprepared for the continued day and night pressures of forced group therapy by other prisoners analyzing their behavior. In time, and under completely controlled circumstances, they were converted.

*Mechanisms of conversion*

We already know much about the mechanisms that brought about the conversion of the Ricketts. In a recent study, a well-known British psychiatrist has described how conversions have been obtained in religion, psychiatry, and in politics through the years, and how these practices are closely related to the discoveries made by Pavlov regarding the limits of conflictive stimuli which dogs can withstand.[109] This study describes techniques that are closely related to the techniques attempted over a longer period of time on the Ricketts and on a mass scale on U.S. Army prisoners during the Korean conflict.

In the case of the Army prisoners during the Korean conflict, there is no doubt that the unpopularity of that war, the particular personal background of those who stayed, and the lack of preparation and discipline of the soldiers had much to do with their low resistance. In the case of the Ricketts the process required full control over them and took a considerable amount of time.

Can significant advances be made in these techniques? As Dr. Leonard Carmichael, psychologist and head of the Smithsonian Institution, puts it:

> It is not calculated to quiet the thought that a breakthrough is possible in a scientific procedure that would allow the direct manipulation from the outside of the wellsprings of individual human behavior.[110]

*Will drugs provide new controls?*

In 10 years biologists and biochemists will know a great deal more about drugs that neutralize abnormal substances in the brain, and about the chemistry of the brain itself. Neurochemists are exploring the chemistry of the mind by learning how chemical stimulation leads

[107] Yet, at the same time, U.S. Marine prisoners and Turkish prisoners demonstrated a much greater ability to resist similar enemy pressure. Air Force pilots were subjected to violence and torture to make them confess to germ warfare.

[108] See Allyn and Adele Rickett, "Prisoners of Liberation," New York, Cameron Associates, 1957.

[109] See William Sargent, "Battle for the Mind," New York, 1957, and the chapter on "Brainwashing," in Aldous Huxley, "Brave New World Revisited," New York, Harper, 1958. pp. 72-83.

[110] Leonard Carmichael, "Science and Human Nature—Retrospects and Prospects," Proceedings of the Borden Centennial Symposium on Nutrition, New York, 1958, p. 136.

to different kinds of behavior. Attempts are being made to find the exact sites of mental illness and perhaps even the structure of an abnormal molecule (or molecules) that may be a basic cause of the mind's malfunction. Other investigators are seeking drugs to return malfunctioning minds to normal.

Drugs that in some way or another affect the chemistry of the brain (reserpin, chloropromazine, meprobromate) are already in widespread use. Another drug causing much interest among pharmacologists, psychiatrists, and brain physiologists is LSD–25 (lysergic acid diethylamide), which is a perception-improver and a vision-producer. More control of the mind is expected, through increased knowledge and improved techniques of using these drugs, as well as the discovery of even more specific and useful drugs.

It is possible that within 10 years, as greater understanding of the chemistry of mental illness is attained, the new drugs constantly being developed could become more powerful, or more specific. They could be effective as a mass euphoric, or they might be used to heighten the suggestibility of a population.

*4. Need for policy: Democracy and the use of the sciences of human behavior*

All the developments described here offer possibilities for both good and evil. On one hand they offer the possibility of greater understanding, better communication, and improved means to influence behavior of citizens in desirable ways. For example, drugs could be used to increase greatly a country's usable pool of minds by virtually curing mental illness. On the other hand, superior techniques of thought control and drugs that affect behavior might provide totalitarian regimes with means to extend their influence over large populations.

The developments in drugs and other thought-control possibilities may seem terrifying. In fact, they are terrifying if improperly used. Yet in the past, societies have been confronted with other powerful thought modifiers. Social controls of the use of alcohol, morphine, and opium indicate that society is not powerless in controlling agents that are dangerous to its survival. Will society find the necessary social mechanisms to control the potential abuses of man's future control over behavior? Over ideology? Will man communicate and cooperate with man, or will some men control most men?

To what extent can democratic governments use existing and future advances in the sciences of human behavior? To what extent can this knowledge be used in foreign policy?

Many corporations in this country make extended use of "consumer motivation research" to sell their products and of various aspects of applied psychology to design them. It is probable that techniques of consumer motivation research and psychological design could effectively be applied in the conduct of certain foreign policy programs. Quite evidently, foreign policymaking is not an exercise in increasing commercial sales volume. It brings a shudder to contemplate a foreign policy oriented at the type of communications that so effectively relate the consumption of a given product with some unconscious want or desire. Yet the same techniques used to identify the unconscious wants or desires which the advertiser plays upon might

also be used to better understand the forces motivating Americans and people in other countries.

An objection voiced by many thoughtful observers is that it is improper for a democratic government to attempt consciously to influence people's behavior. However, any democratic government already uses many means of influence (force or the threat of force, punitive or incentive taxation, grants, loans, propaganda) to achieve its aims. Probably the unfamiliarity and potential power of newer methods lead to a certain reluctance to find out what they are, how effective they might be, and to consider whether they should be used, if at all.

Present suspicion of, or reluctance to use, scientific understanding of human behavior can, in fact, be compared with early attitudes toward understanding of the outside physical world. In the 17th century, scientific knowledge was suspect [111] because of the fear that it would lead to materialistic instead of spiritual endeavors by mechanically explaining the nature of the universe. The philosophy of science in the 20th century is still very far from mechanically explaining the universe and appears instead to be getting further away from such a possibility. Similarly, man's understanding of human behavior need not reduce the importance of such values as freedom and democracy, but instead can provide guidelines and a basis for the necessary social technology to permit man to keep up with the advances of the physical and biological sciences and their technological results. A better understanding of human motivations and of the processes which facilitate or impair meaningful communication could be used both to bring foreign policy problems more adequately to the attention of the American people and to reduce unnecessarily large areas of misapprehension and mistrust in relations with other peoples.

[111] Is there a similarity between the attacks on the early physical scientists and present-day suspicion against, or reluctance to use, the developing science of human behavior?

"Thursday, February 25, 1616, the Lord Cardinal Mellini notified the Reverend Fathers, the Assessors, the Commissary of the Holy Office that the censure passed by the theologians upon the propositions of Galileo—to the effect that the sun is the center of the world and immovable from its place, and that the Earth moves, and also with a diurnal motion—had been reported; and His Holiness has directed the Lord Cardinal Bellarmine to summon before him the said Galileo and admonish him to abandon the said opinion; and in case of his refusal to obey, that the Commissary is to enjoin on him, before a notary and witnesses, to command to abstain altogether from teaching or defending this opinion and doctrine and even from discussing it: and, if he do not acquiesce therein, that he is to be imprisoned." (See Giorgio de Santillana, "The Crime of Galileo," Chicago, 1955, p. 122.)

# IV. POLICY FOR THE FUTURE

## CHAPTER 7

## POSITIVE USE OF SCIENCE TO ACHIEVE INTERNATIONAL GOALS

What is the outlook for the rate of discovery and invention? Should policymakers assume that future scientific developments will be fewer and less disturbing? Should they be prepared for continued occurrence of scientific developments at the present high rate? Or should they expect a still more rapid rate, implying a still greater necessity for readjustments in foreign policy to meet changing conditions?

The last alternative is the most probable—subject to one overriding reservation: that all-out war using modern weapons will be avoided. Such a war could destroy centers of social organization and of science and leave the survivors (if any) at quite a different level of civilization. But in the absence of catastrophic war it is likely that science and technology will develop even more rapidly in the future than in the past. The evidence for this view is compelling.

### A. THE ACCELERATING RATE OF DISCOVERY AND INVENTION

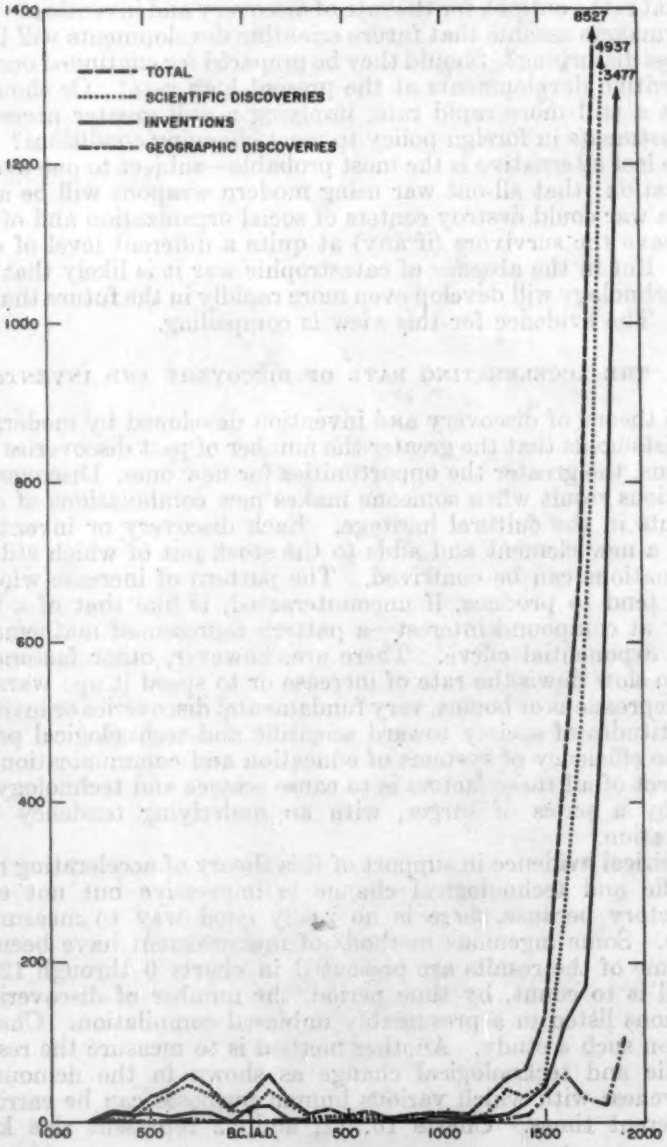
The theory of discovery and invention developed by modern social scientists holds that the greater the number of past discoveries and inventions, the greater the opportunities for new ones. Discoveries and inventions result when someone makes new combinations of existing elements in the cultural heritage. Each discovery or invention becomes a new element and adds to the stock out of which still newer combinations can be contrived. The pattern of increase which this would tend to produce, if uncounteracted, is like that of a sum of money at compound interest—a pattern represented mathematically by an exponential curve. There are, however, other factors which tend to slow down the rate of increase or to speed it up: wars, economic depressions or booms, very fundamental discoveries or inventions, the attitudes of society toward scientific and technological progress, and the efficiency of systems of education and communication. The net effect of all these factors is to cause science and technology to expand by a series of surges, with an underlying tendency toward acceleration.

Empirical evidence in support of this theory of accelerating rates of scientific and technological change is impressive but not entirely satisfactory because there is no really good way to measure such change. Some ingenious methods of measurement have been tried, and some of the results are presented in charts 9 through 12. One method is to count, by time period, the number of discoveries and inventions listed in a presumably unbiased compilation. Chart 9 is based on such a study. Another method is to measure the results of scientific and technological change as shown in the demonstrated effectiveness with which various human purposes can be carried out at different times. Charts 10, 11, and 12 represent this kind of

measurement. They cover human speed, range of projectiles, and power of explosives. These examples have been chosen for their pertinence to the influence of science and technology on the environment within which foreign policy must be framed.

CHART 9

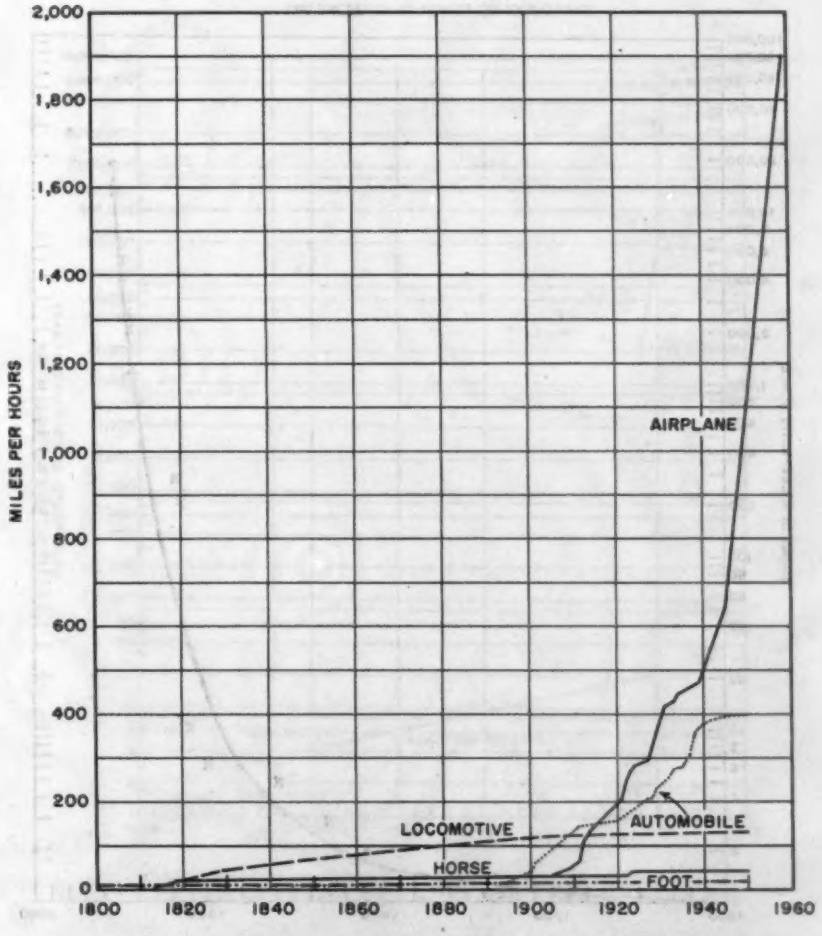
NUMBER OF SCIENTIFIC DISCOVERIES AND INVENTIONS FROM 800 B.C. TO 1900 A.D., BY CENTURIES




SOURCE: Pitirim A. Sorokin, Social and Cultural Dynamics, Volume Two, Fluctuations of Systems of Truth, Ethics, and Law, New York, American Book Company, 1937, pp. 134-37.

CHART 10

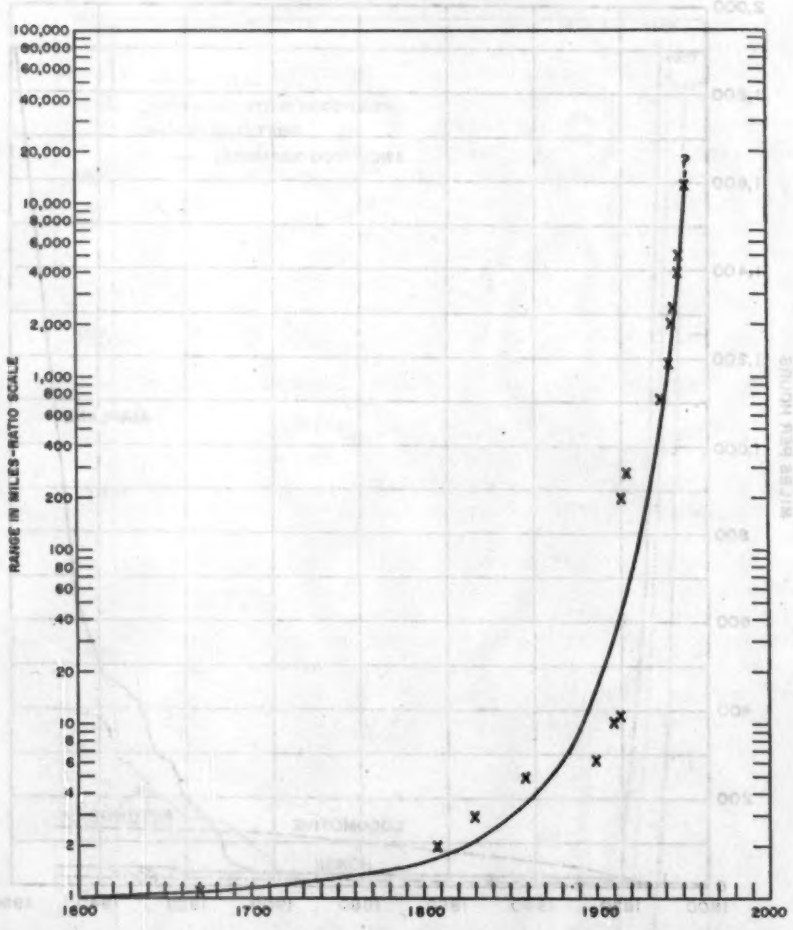
THE ACCELERATING INCREASE IN HUMAN SPEED
As Measured by World Records




SOURCE: Harnell Hart, The Technique of Social Progress New York, Henry Holt and Company , 1931, pp. 75-78; same, "Technological Acceleration and the Atomic Bomb, American Sociological Review, June, 1946, pp. 283-5; same, in Technology and Social Change, by Allen and others New York, Appleton-Century-Crofts, 1957, pp. 32-34. Latest airplane data added.

CHART 11

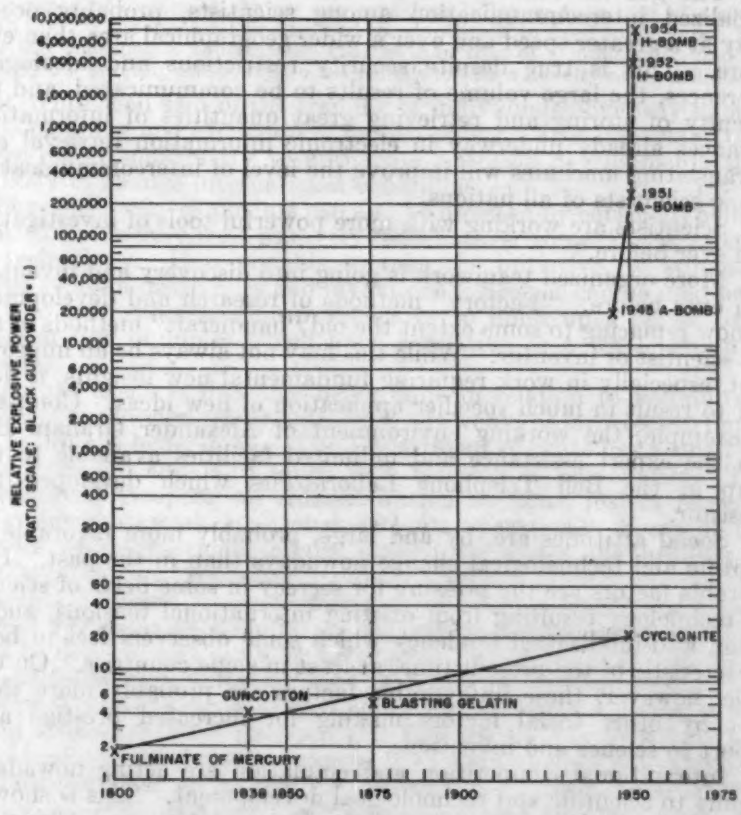
INCREASING RANGE OF PROJECTILES, INCLUDING BOMBS CARRIED BY AIRCRAFT




SOURCE: Harnett Hart, "Acceleration in Social Change," in Allen, Francis R., and others, Technology and Social Change, New York, Appleton-Century-Crofts, 1957, table p. 36 and references there cited.

CHART 12

THE INCREASING POWER OF EXPLOSIVES




SOURCE: Hornell Hart, "Acceleration in Social Change," in Allen, Francis R., and others, Technology and Social Change, New York, Appleton-Century-Crofts, 1957, pp. 40-43.

*Concrete factors at work today*

Specific present-day factors are working powerfully in the direction of speeding up scientific and technological development. Among them are:

1. The total number of trained scientists and technologists is greater today than ever before, and the number is growing rapidly. This is true not only in the United States but generally throughout the world, especially in the Soviet Union and China.

2. More funds are being spent on research and development than ever before.[1]

3. The general diffusion of new ideas and techniques, and also specialized intercommunication among scientists, probably occurs today at a greater speed and over a wider geographical area than ever before. This is true despite security restrictions and ideological differences, the large volume of results to be communicated, and the difficulty of storing and retrieving great quantities of information. Advances already underway in electronic information retrieval and in translating machines will improve the level of intercommunication among scientists of all nations.

4. Scientists are working with more powerful tools of investigation than ever before.

5. More organized teamwork is going into discovery and invention than ever before. "Factory" methods of research and development are now replacing to some extent the old "handicraft" methods of the lone scientist or inventor. While this may not always be an improvement, especially in work requiring fundamental new insights, it does tend to result in much speedier application of new ideas. Compare, for example, the working environment of Alexander Graham Bell with the expert assistance and unlimited facilities available to the group in the Bell Telephone Laboratories which developed the transistor.

6. Social attitudes are, by and large, probably more favorable to scientific and technological change nowadays than in the past. Unfavorable factors are the pressure for secrecy in some fields of science and technology resulting from existing international tensions, and a certain anti-intellectual tendency which some observers feel to be a characteristic of the present time, at least in some countries. On the whole, however, these unfavorable factors are probably more than offset by other social factors making for increased prestige and support to science and invention.

7. International competition and emulation are acting nowadays as spurs to scientific and technological development. This is shown, for example, in the campaigns of the Soviet Union and China to overtake the United States and Britain, and in the response in this country to the Russian sputniks.

While this is the overall picture, there are significant differences in the degree to which rapid advance is being promoted in the various fields of science and technology. The fields currently receiving the largest concentration of effort, expressed in manpower, funds, and other encouragements of organized society, are those connected with military strength. Next are those considered likely to develop

[1] "If, as seems likely, the United States spends approximately $120 billion on R. & D. during the sixties, this will substantially exceed the Nation's total investment in science and technology in the 183 years between 1776 and the present date." (Francis Bello, "The 1960's: A Forecast of the Technology," Fortune, January 1959, p. 200).

salable commodities or to lower the costs of production—these are the aims of most industrial research. Low in allocation of effort and hence in probable speed of development are two fields of special interest to foreign policymakers: (1) Scientific effort specifically directed toward peaceful achievement of foreign policy objectives, and (2) basic problems of human relations and social organization, including international aspects of these problems.

### B. POSITIVE USE OF SCIENCE

Formerly, as Alfred North Whitehead put it—

> the timespan of important change was considerably longer than that of a single human life. Thus mankind was trained to adapt itself to fixed conditions. But today this timespan is considerably shorter than that of a human life, and accordingly our training must prepare individuals to face a novelty of conditions.[2]

What Whitehead said of the training of individuals obviously applies to the planning and execution of foreign policy. It is important that foreign policy makers try to anticipate scientific developments that are likely to change international conditions.

But scientific developments can also be directed by conscious policy. We need not merely wait passively for whatever comes out of science and technology. It is possible to take the initiative, to stimulate desired types of discoveries and inventions. Science can be used positively to help solve specific problems or to build up a better basic understanding of topics which have a relation to a whole group of problems.

To what exent is this now being done in relation to nonmilitary aspects of our foreign policy problems? It would be incorrect to imply that nothing is being done. The Department of State has a small research program and is in touch with research in universities. The International Cooperation Administration at times fosters research or development work connected with its operations. Some of the analyses of international affairs carried on under the heading of "intelligence" and "reporting" embody a certain amount of scientific research. Military research programs oftentimes yield results that are also pertinent to nonmilitary aspects of foreign relations (more could be done to sort out such results and, where appropriate, to get them declassified). Efforts of the U.S. Government to promote peaceful applications of science as part of our foreign policy are exemplified in the atoms-for-peace program put forward by the President and in the leading role of this country in the International Conferences on the Peaceful Uses of Atomic Energy and the International Atomic Energy Agency. But, on the whole, the extent to which science is consciously being called upon to improve the formulation or execution of our foreign policy is quite small compared with the conscious use of science in connection with military, industrial, agricultural, and medical problems, particularly small when one considers the urgent need to find new approaches to foreign policy problems.

Is the relative neglect, thus far, of the tools of scientific research and development where nonmilitary aspects of foreign policy are concerned due to lack of problems? This obviously is not the case. Is it because there are not research approaches capable of dealing with such problems? This is true of some foreign policy problems, but there are

[2] Alfred North Whitehead, "On Foresight," printed as an introduction to Wallace Brett Donham's "Business Adrift," New York, Whittlesey House of McGraw-Hill, 1931.

many of which it is not true. Some of these will be described below. Furthermore, some of the problems for which existing scientific knowledge and techniques are inadequate (and the greatest inadequacies relate to the human problems, which are central in foreign policy) might ultimately become capable of solid attack if more encouragement were given to basic research in the relevant sciences. Is the underemphasis on research programs in nonmilitary aspects of international affairs due to lack of well-conceived approaches to the use of research in the executive agencies concerned, or to lack of support by Congress? We suggest that the committee review the situation.

### C. WHAT STEPS COULD BE TAKEN?

If the committee feels that a more active use of science is called for in order to achieve America's international goals, a three-part program could be considered:

First, the committee could request the executive branch, in cooperation with the committee's own staff and such other Government agencies and private groups or individuals as might be helpful, to prepare a carefully considered list of specific foreign policy problems on which research and development would appear to offer good prospects of beneficial results, and to propose ways of getting work on these problems stepped up or started.

Second, the committee could similarly request the executive branch, in cooperation with the committee's staff and others, to prepare a carefully considered list of selected fields in which basic scientific research offers a good probability of producing results that will be beneficial in the formulation and execution of American foreign policy but which are not now being cultivated to the desirable extent, and to propose what might be done to double or triple the amount of high-quality talent devoted to basic research in these selected fields within the next 5 to 10 years. Among the most important fields for this purpose are several in the psychological and social sciences. Any measures suggested for stimulating basic research should, of course, be ones that encourage the freedom of inquiry which fosters progress in basic science, and they should leave large areas of discretion to the researchers.

Third, the committee could consider, or might ask the executive branch to propose new steps that might be taken in order to make use of the international proclivities of science and scientists to build bridges of understanding between our country and other nations.

Such a three-part program would, first of all, make conscious and systematic use of science in the formulation and execution of foreign policy. Second, it would stimulate the development of basic science in those fields where foreign policy problems may require new scientific insights. Third, it would favor international approaches to scientific research and to scientific communication when such approaches are in the long-term interest of the United States.

Suggestions relating to each of these three lines of action will be presented briefly.

*1. Applications of science to specific foreign policy problems*

The following groups of problems, among many others, should be considered in order to determine what scientific research bearing on them is now underway, within the Government and outside, and what

further research efforts would be helpful in the formulation and execution of foreign policy:

(*a*) *Problems of foreseeing scientific developments and their foreign policy impacts.*—This report does not claim to be exhaustive. It has not been possible to canvass thoroughly all the many fields in which significant scientific developments might arise. Some of the possibilities mentioned need additional study and all need to be kept under review, for new developments often come rapidly. It is important, for example, that the possible international impacts of synthetics described in this report be studied more thoroughly and be continually reassessed and that alternative policy responses open to the United States be analyzed and evaluated. Should not a responsibility be established within the Government for continuing review of prospective scientific developments and their foreign policy impacts?

(*b*) *Problems pertaining to new frontiers beyond national boundaries: oceans, polar regions, atmosphere, space.*—In addition to making sure that the United States is not to lag behind in the physical and biological knowledge required for advances in these fields, it is also important to encourage studies of a legal, political, and administrative character.

(*c*) *Problems pertaining to food and population.*—Are we doing all that can be done to make positive use of science for developing and adapting promising methods by which to increase food production where food is scarce, to make the most effective use of American surpluses, and to explore population control possibilities?

(*d*) *Problems of planning for new world relationships in production and trade.*—As a result of the spread of modern technology to formerly underdeveloped countries, what new competition and what new market opportunities will confront our own producers? Can long-term analyses be made, under varying assumptions, of world supplies of raw materials and energy and of world trade patterns? Could such an undertaking provide foreign policymakers with a more accurate vision of the nature of the world with which the United States will deal in the future? How can the United States and other nations effectively cooperate in the development of new exports from those countries in which new synthetics may endanger stability and thereby affect the security of the United States?

(*e*) *Problems of communication with other nations.*—Can the social sciences be stimulated to provide better insights concerning the goals of other nations and the interrelationship between our goals and theirs? Such analysis would deal with the political and economic systems and social movements of other nations, their aspirations and fears, their images and attitudes concerning the United States and concerning other countries, especially the Communist countries, and other important characteristics. The possibility of speeding up the development of scientific techniques for sampling attitudes and motivations in cultures other than our own deserves particular exploration. Can improved methods be found for measuring the effectiveness of our information programs and our educational and cultural exchange programs? What are the social-psychological factors involved in making such programs more effective? Could the creation of centers for research and training in techniques of international diffusion of knowledge or in techniques of ideological warfare

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ultimately provide U. S. executive agencies with improved techniques of international communications? [3]

(*f*) *Problems of international political organization, law, and administration.*—What further research on political systems and legal and administrative systems might assist in finding the best ways to proceed in strengthening the United Nations and attempting to move toward a world rule of law?

(*g*) *Problems of arms control and disarmament.*—Not only do the technical problems of arms control and of inspection systems to prevent violations need constant research, but also it would be well to explore the economic repercussions and adjustments which we should be prepared to deal with in case a substantial measure of arms reduction should some day become possible.

(*h*) *Problems in assisting the economic and social development of underdeveloped countries.*—An additional push to research on desalting of water, on applications of solar energy, and on other similar possibilities might produce breakthroughs which would assist the United States in its policy of helping underdeveloped countries to raise their levels of living. Progress in scientific understanding of the social and economic processes of development and international comparative studies of development methods could be encouraged to the same end.

Each of these groups of problems (and others not included among these examples) could be broken down into feasible and useful programs for scientific research. To illustrate, we shall briefly suggest possible lines of research attack on the last two of them: disarmament, and underdeveloped countries.

*Problems of arms control and disarmament*

Arms control and disarmament require both extensive planning and development of systems, including development of special equipment permitting adequate monitoring of agreements. Yet, until now, very little funds and effort have been devoted to research specifically oriented to the development of such systems.

The problems of arms control are more complicated than most other military weapons problems, because one must be concerned with the performance of a large integrated system. Though integrated system problems do arise in conventional military planning—the air defense system is one example—most military weapons can be studied as isolated units and then later integrated into the overall military systems.

In addition, arms-control proposals could conflict with weapons development and deployment plans and may consequently be considered dangerous to the national security. In order for such proposals to have even the slightest possibility of being accepted, it is necessary to evolve proposals that can be shown conclusively to present less danger to the security of the country than does continuing the arms race. Such demonstrations require extensive study.

Weapon systems capable of being used in a surprise attack are evolving very rapidly. Changes in the character of offensive weapons can alter radically the requirements imposed upon an inspection and control system as well as the range of possibilities open to the designer

[3] Edward W. Barrett made a somewhat similar suggestion 6 years ago when he suggested an institute for research and training in international information and persuasion, to provide both training and linkage between the academic and government communities. (See Edward W. Barrett, "Truth Is Our Weapon," New York, 1953, p. 285.)

of such a system. In future years it will not only be necessary to demonstrate that a proposed inspection system can cope with the aircraft, missile, and submarine threats that are now anticipated, but also with a large number of weird new weapons proposed by the critics of the specific system.

In the past there has not been adequate time to investigate fully the technical or logistic needs of given inspection tasks or to develop the equipment required for the task. The recent negotiations on nuclear test suspension provide an example of this difficulty. Insufficient experimental work had been done prior to the negotiations, and consequently the technical group at the conference had to depend upon theoretical calculations and extrapolations from inadequate data. Furthermore, though it appears technically simple to make much better seismic detection equipment than is now available, it would take 2 or 3 years to do so. Consequently initial planning of an inspection system must be restricted to use of the very inadequate equipment now available. A continuing research and development group working in the field of arms-control techniques could anticipate such problems and carry out development work in advance of needs. Hundreds of thousands of men are engaged in the development of new weapons. Yet we know of no single group in the United States working full time on technical problems of arms control.

The technical problems requiring better understanding include problems related to observation techniques, such as radar, aerial photography, ground observers, adequate seismic means for monitoring atomic explosions, etc., problems involving the communication and data processing systems, and the questions of the performance of systems created by combining various components.[4]

What appears to be required is a continuing study group, that is, a center, having facilities for carrying out analysis and experimentation. The group should also have ample funds to subcontract study and development work. Such development work would undoubtedly be costly, but there is little doubt that the security of America would be enhanced by such an effort.

*Development of underdeveloped countries*

As noted in chapter 4, it is the policy of the United States to aid the efforts of the peoples of economically underdeveloped areas to develop their resources and improve their working and living conditions. Implementation of this policy offers scope for contributions from more fields of science than any other aspect of our foreign policy.

To illustrate the numerous possibilities, table VI has been prepared. It is by no means comprehensive. The selected examples of needed scientific or technological development are grouped under the major fields—physical, biological, psychological, and social—to which they are most directly related. In the right-hand column of the table, a tentative judgment is expressed as to the stage of scientific and technological development at which work is now required. Some problems of underdeveloped countries can be met simply by taking over techniques already known in other parts of the world, though in most cases at least some "adaptive invention" is necessary. Other problems

[4] See also the report (released June 12, 1959) of the Science Advisory Committee's panel on seismic improvement. The panel recommended further research in the comparatively neglected field of seismology, which would be likely to produce new ideas and approaches that would improve monitoring systems (Science, vol. 130 (July 3 and 10, 1959), pp. 26–28, 86–88).

require more basic invention, and still others may not be solvable until new principles are discovered, which means that the quest for the solution requires basic as well as applied scientific research. Basic research may, of course, also open the way to better answers for problems that are already being handled fairly well by known methods.

Should not an appropriate agency of our Government have an office of research and development concerned with problems of underdeveloped areas? It could initiate a systematic program for identifying problems such as those in table VI, where scientific and technological breakthroughs would help to speed up the development process. It could then stimulate research on these problems, either in the United States or abroad.

TABLE VI.—*Examples of problems on which scientific research and development would materially assist underdeveloped countries*

[This tabulation is by no means exhaustive]

| Selected problems | Stage of scientific and technological development at which work is presently required | | | |
|---|---|---|---|---|
| | Basic science | Invention of new or improved technology | Adaptive invention (to fit known technology to other countries and cultures) | Introduction and spread of known technology |
| | (1) | (2) | (3) | (4) |
| A. PHYSICAL | | | | |
| 1. Simple and cheap power sources for villages and towns: | | | | |
| (a) Electric generator driven by animal power, by energy from agricultural crops or waste materials, or other locally familiar resources. | | | X [1] | X |
| (b) Gas from agricultural wastes, cow dung, etc. | | | X [1] | X |
| (c) Wind-powered pump and electric generator | | | | X |
| (d) Solar energy uses | X | X | X | X |
| (e) Efficient storage of energy (for intermittent operation of wind, solar, or other sources). | X | X | | |
| (f) Small nuclear power systems | X | X | | |
| 2. Improved but simple and cheap housing materials and construction methods: | | | | |
| (a) Hand-operated press and stabilizers for making durable building blocks from common soils. | | | X [1] | X |
| (b) Designs and insulation methods adapted to tropical climates and local materials. | | | X | X |
| 3. Abundant and cheap water for irrigation and industrial uses: | | | | |
| (a) Control of runoff, river valley development, etc. | | | X | X |
| (b) Locating underground water | X | X | X | X |
| (c) Well-drilling techniques | | | X | X |
| (d) More efficient water-raising techniques (e.g., modern pump adapted to local power sources). | | | X [1] | X |
| (e) Solar pump | X | X | X | X |
| (f) Cheap desalting of water | X | X | | |
| (g) Prevention of water storage losses (evaporation inhibitors). | X | X | X | X |
| (h) Reuse of waste water | | | X | X |
| 4. Simple, cheap methods of refrigeration for foods and of cooling of houses: | | | | |
| (a) Solar-powered refrigeration | | X | X | |

[1] Adaptive invention recently made. See ch. 4.

TABLE VI.—*Examples of problems on which scientific research and development would materially assist underdeveloped countries*—Continued

| Selected problems | Stage of scientific and technological development at which work is presently required | | | |
|---|---|---|---|---|
| | Basic science | Invention of new or improved technology | Adaptive invention (to fit known technology to other countries and cultures) | Introduction and spread of known technology |
| | (1) | (2) | (3) | (4) |
| B. BIOLOGICAL | | | | |
| 1. Environmental sanitation: | | | | |
| (a) Simple, cheap, culturally acceptable outdoor latrines and indoor toilets requiring no running water. | | | X | X |
| (b) Simpler and cheaper water purification methods. | X | X | X | X |
| (c) Controls for flies and other pests | X | X | X | X |
| 2. Special disease problems (schistosomiasis, hepatitis, filariasis, brucellosis, trachoma, dysenteries, etc.). | X | X | X | X |
| 3. Food preservation: | | | | |
| (a) Storage methods adapted to tropical conditions. | | | X | X |
| (b) Adaptations in conventional preservation methods (canning, drying, etc.). | | | X | X |
| (c) Unconventional methods (irradiation? others?). | X | X | | |
| 4. Improvement in food crops and animals: | | | | |
| (a) Selection and genetic improvement of promising local plants and animals. | | X | X | X |
| (b) Local adaptation and improvement of plants and animals imported from abroad. | | | X | X |
| 5. Control of population growth: | | | | |
| (a) Good, cheap oral contraceptive or its equivalent. | X | X | | |
| C. PSYCHOLOGICAL AND SOCIAL | | | | |
| 1. Improvement in techniques of planning development programs: | | | | |
| (a) Better means of anticipating social impacts of introducing scientific and technological changes. | X | X | X | X |
| (b) Better theory and methods for determining best allocation of limited funds among diverse projects. | X | X | X | X |
| (c) Better organization, administration and training methods for planning agencies. | X | X | X | X |
| (d) Comparative studies and improved techniques to assist in anticipating future needs for trained manpower. | X | X | X | X |
| 2. Simple, cheap methods of mass education: | | | | |
| (a) Special adaptations of conventional methods of teaching and teacher training. | | | X | X |
| (b) Use of radio, TV, films, etc., in new ways | | X | X | X |
| (c) Unconventional methods, such as teaching machine. | X | X | X | |
| (d) Inexpensive methods of meeting special educational problems, such as communicating birth control information to illiterate people. | X | X | X | X |
| 3. Methods of introducing agricultural and rural improvements; communicating effectively with people, and motivating them to adopt better practices: | | | | |
| (a) Finding the most efficient agricultural extension and rural community development methods and spreading them. | | X | X | X |
| (b) Better understanding of special sociological problems in rural areas of particular cultures and adjustment of technical assistance methods accordingly. | X | X | X | X |

TABLE VI.—*Examples of problems on which scientific research and development would materially assist underdeveloped countries*—Continued

| Selected problems | Stage of scientific and technological development at which work is presently required | | | |
|---|---|---|---|---|
| | Basic science (1) | Invention of new or improved technology (2) | Adaptive invention (to fit known technology to other countries and cultures) (3) | Introduction and spread of known technology (4) |
| C. PSYCHOLOGICAL AND SOCIAL—continued | | | | |
| 4. Methods of introducing modern industrial techniques and meeting problems of industrialization: | | | | |
| (a) Improvement and spread of techniques of management training, worker training, industrial counseling, organization of industrial estates, etc. | X | X | X | X |
| (b) Ways of finding, stimulating, and developing business and industrial entrepreneurship in nonindustrial cultures. | X | X | X | X |
| (c) Urbanization problems, and possibilities of decentralizing industry. | X | X | X | X |
| 5. Governmental methods compatible with democratic ideals but more suitable to special circumstances of underdeveloped and newly independent countries than methods copied from highly developed countries. | X | X | X | X |
| 6. Better methods of identifying the most suitable persons for "overseasmanship" and methods of training and briefing them. | X | X | X | X |

## *2. Basic scientific research*

A prevalent tendency of legislators, administrators, and business executives in dealing with scientific research is to underestimate the importance of basic research. Basic research means research designed to produce better understanding of some phenomenon and only indirectly to solve a practical problem.

Every electric motor and generator in the world stems from the basic research in which Faraday discovered relationships between the flow of current in a wire and the movement of the wire in a magnetic field. It is related that after a public lecture in which he had demonstrated that plunging a magnet through a coil of wire would deflect the needle on a galvanometer, a lady asked him, "But what is the use of it?" and Faraday replied, "Madam, what is the use of a newborn baby?" [5] Experience has demonstrated hundreds of times that important practical accomplishments are likely to flow from newborn theoretical understanding. Pasteur's linking of microorganisms to disease, Einstein's statement of mathematical equivalence between matter and energy, Keynes' theoretical development of the interrelations among savings, investment, income, and employment, are examples from the biological, physical, and social sciences of basic research which has contributed to very important practical results.

Looking to the future, basic research in the movements of air masses and ocean currents might open the way to climate control. A better theoretical understanding of the processes of economic and social development may be one of the best ways to make our development aid

[5] This remark is often attributed to Faraday, but apparently Benjamin Franklin said it first. See Nicholas G. Demy, "Verifying Useless Knowledge," Science, vol. 123 (Apr. 27, 1956), p. 725.

programs more effective. Adequate understanding of the natural photosynthesis performed by all green plants might enable man to learn how to convert light energy into chemical energy on an industrial scale and open wide possibilities for food supply, energy supply, and new materials.

*Need for better theory*

As a basis for wise formulation and effective execution of foreign policy we do, of course, need more facts and more reliable flows of factual information. But this is not the major need. The major need is for better interpretation of the facts, for better understanding of their meaning in terms of our aims, ideals, and plans, and for better founded notions about the probable effects of this course of action or that. In other words, the major need is for better theory, meaning by theory what the scientist means—that is, a mental model or map of the way things seem to be arranged in the real world, of the way things interact, of cause and effect. Better theory comes from basic research.

To put the matter this way challenges a widespread but nevertheless mistaken assumption that the "practical" man is one who avoids theory, and that practical policymakers can afford to be contemptuous of theory. The fact is that we cannot perform any rational act without relying on theory. When we walk across a room we rely on the theory that gravity will bring our feet down in certain ways and that the location of the furniture will correspond in predictable ways to our visual images. Common theories like these are so thoroughly verified by daily experience that we rely on them automatically without need for conscious thought. But let there be a new situation in the room—let the floors and the walls of the room be tilted in an unconventional way, let there be reflecting mirrors that complicate our visual reconnaissance of the path we propose to follow—then our unquestioned automatic, conventional theories become misleading. We stumble, unless we make an effort of will and imagination and devise and test better theoretical models by which to guide ourselves through the unaccustomed situation.

The modern world of political, economic, and social interrelationships among nations is like this changed room. Even more, it is continuing to change all the time and will probably change in the future at a faster and faster rate, partly because of the accelerating speed of scientific discovery and invention. In such a world, those concerned with the making and implementing of foreign policy will need all the help they can get from sophisticated, tested, and continually revised theory about human behavior and about the interaction of political, economic, and social organizations and relationships. Conventional wisdom—that is, loosely formulated theories tested only in a casual and nonrigorous way and under past conditions which may now be altered—is not an adequate guide to policy in such a world.

*One example: Motivational problems and the theory of deterrence.*—Consider the theory of "deterrence," on which a major part of our policy for preventing nuclear attack is built. On the basis of this theory, the United States and its allies are spending billions of dollars, probably hundreds of billions over the next decade. More important, we are risking our lives and the fate of the world on it.

Yet, have the fundamental psychological assumptions of the theory of deterrence received as careful analysis and testing as they deserve?

Could not more be done toward deeper understanding of motivational problems, while we continue in the meantime to use the best knowledge and practical intuition available? Might it not be possible to develop a better understanding of alternatives to deterrence in influencing the behavior of antagonists?

As soon as one begins to explore the basis for this apparently simple theory, it becomes clear that the whole concept bristles with questions. Deterrence (Latin, "de-terrere"—out of terror or fear) means restraint through fear or by risk of unpleasant consequences. In what situations and to what extent is the risk of unpleasant consequences rationally weighed in arriving at political decisions? Similarly, when do irrational or emotional responses play a significant role? What is the impact of fear on human behavior under various conditions? Under what conditions will it encourage rational responses, and under what conditions will it provoke irrational responses that produce the very consequences feared? How does the threat of mass punishment enter into the decision-making processes of various political systems, including the systems we are dealing with in the world today, or modified systems that may arise in the next decades?

There is rather definite evidence, based on experiments with animals and on observation of humans, that a high level of fear in individuals (1) impairs the cognitive processes, (2) lessens the perception of available alternatives of behavior, and (3) tends to produce a reversion to behavior patterns learned in an earlier situation, even though these are no longer applicable. There is also evidence that when behavior is restrained by fear the impulse itself is likely to continue and find an outlet somewhere else, the original motivation being unchanged. Have such findings of individual psychology any relevance to the behavior of groups, particularly highly organized groups like political states, or to the behavior of their decision makers?

Almost at the other pole from the theory of deterrence as a means of influencing the behavior of potential enemies we have theories propounded by highly regarded religious leaders. Do some of their insights have a scientifically demonstrable basis? Research in industrial human relations, which has been a factor in improving labor-management policies and personnel administration, may have something to contribute to international relations. Can all these possibilities be given more intensive scientific study, and can more effective ways be invented for applying to practical international problems whatever new knowledge is discovered?

These are difficult questions, and there are no simple answers to them. But it is at least possible that imaginative, carefully designed, basic research could eventually throw light on them.

*Special attention needed to advancement of psychological and social sciences*

Nearly all branches of science can contribute in some way to coping with one or more of the multitudinous problems that concern foreign policymakers. But foreign policy problems (excluding military aspects) are overwhelmingly human ones. At the same time, the psychological and social sciences, to which foreign policymakers ought to be able to look—and do look, to quite a significant extent—for insight and help, are the least well developed and least well supported of the major scientific groups. While no one should expect that by

augmenting the funds and personnel for basic research in these sciences there will be quick and handy solutions to problems of human relations, there is ample basis for believing that more effort in this field could lay the groundwork for considerably better understanding of the nature of some of the problems that plague foreign policymakers and be of substantial help to them.[6]

"Past threats have impelled the Government into broad and effective research programs in the physical sciences. Today, the Nation is faced with new threats in other areas. They are just as urgent as military problems; they demand a high level of effort and attention. They are problems of communication between peoples; of helping new countries knit the fabric of a good, productive life * * * of 'security' in its broadest sense; of extending the concept of freedom so that it becomes meaningful and important to others. These are problems where research can help develop human sciences, where the solutions are to be found in social inventions, just as research on physical phenomena has resulted in physical inventions. Research can make many contributions to the better understanding of the invisible but very real forces affecting human behavior, human relations, and human institutions." [7]

*3. Encouraging the international proclivities of science and scientists in order to build bridges of understanding*

Historically, science has not been a good respecter of national boundaries. The influence of its discoveries has been worldwide, and their practical applications in technology have brought the peoples of the world into a more and more intimate interdependence. The process of scientific observation itself frequently has to jump country borders and "curtains" in order to be sound and effective. This applies to the study of geophysical phenomena—meteorology, oceanography, the earth's electrical field—as demonstrated in the International Geophysical Year. It also applies in the scientific study of animals and plants and of human cultures and political and social organizations. Scientific talent and the attitude of mind which makes for progress in science are found to some degree in every country. Scientific literature is worldwide. Scientists are usually eager to communicate with each other and are able to work together on common problems, despite language differences and the psychological and political barriers imposed by nationalisms and by conflicting ideologies.

These international proclivities of science and scientists can be used positively as a unifying force, both in cementing good relations between our Nation, our allies, and other friendly nations; and also, hopefully, as a means of building a few bridges of understanding to the other side in the cold war. Unless this latter can be done, there is little hope for the survival of humane civilization under the conditions

[6] See, for example, the article by Stephen C. Brown, of the staff of the Economic Development Division, Department of State (who writes, however, as an individual), "Economic Aid: An Inventory of Problems for Attitude Research," Public Opinion Quarterly, fall 1958, pp. 416–420. He says that government officials of the developing countries, as well as our own, "* * * would welcome any contribution that the research community can make to an understanding of the processes of economic and social change * * *. What people concerned with economic aid need is detached, scientific study of basic attitudes in the less developed societies as they bear upon development problems. Such studies would not contribute directly to the designing of economic development programs but they would, I believe, illuminate the problems in such a way as to permit those actually engaged in such efforts to avoid much waste of time, money and effort." He then discusses 9 topics on which attitude research is needed and comments, "All of the above questions are of direct and immediate importance to the practical management of economic development programs, despite their theoretical appearance."

[7] E. Finley Carter, president of Stanford Research Institute, in a statement to the Committee on Government Operations of the House of Representatives, July 1958.

created by modern science. It is appropriate that science, which has been an important factor in making bridges of understanding essential, can also offer some help in building them.

The U.S. Government is already engaged in a number of activities of the type under discussion, or is encouraging private activities of this sort, and others can be suggested.

*Scientific conferences and personnel interchange*

International scientific conferences in many fields merit further encouragement, as do lively interchanges of scientific personnel at all levels, from students to Nobel Prize winners.

*International research programs*

Some of the research activities for which the need was discussed earlier in this report can be carried on to advantage by international agencies or by cooperating research institutions in a number of countries. This applies to new frontiers of man's science and technology, like the oceans, the atmosphere, the polar regions, and space, and also to research related to development of underdeveloped countries.

The possibility of internationalizing the Arctic, space, and the deep seas merits further examination in the light of the scientific and technological developments that may take place in the not-too-distant future. It might also be worthwhile to examine the possibility of establishing a United Nations weather and climate agency to carry on research and ultimately to have authority over all weather and climate control undertakings.

Funds becoming available through the sale of surplus farm products abroad (Public Law 480) might well be used in part for the establishment of, or for additional support to, universities and research institutes which would cooperate in international research programs.

*An international translation and information retrieval center*

Advances in the fields of mechanized translation and information retrieval offer new opportunities for establishing international means of communication among the scientific communities of the world. The probable future capabilities of machine translation will provide a powerful means by which to reduce the basic language problems faced by mankind. An international translation and retrieval center would particularly encourage advances in the nonmilitary aspects of science, since of course no nation would be expected to provide classified information to such a system.

*Worldwide attack on important problems: An international development year*

The International Geophysical Year, which required several years for its planning and execution, has demonstrated the ability of scientists from the Soviet and western worlds to work together for the planning and carrying out of an important program. Its success was considerable, and its influence seems likely to persist for some time in continuing cooperative research.

The United States might give leadership in establishing another such international endeavor, to be called "The International Development Year—Science and Underdeveloped Areas." The object would be to initiate on a worldwide basis new studies on the key development problems of underdeveloped countries and to stimulate basic

research in those aspects of the physical, biological, and psychological and social sciences from which contributions to the solution of these problems might be expected.

*A United Nations university*

The United States might also take the lead in proposing the establishment of a United Nations university system at the advanced (postgraduate) level, with campuses to be located in various regions of the world. Such a university system could be dedicated to the advancement of science and the humanities in order to discover and develop unifying elements in the values widely held by the different groups and cultural traditions of mankind. It could be planned ultimately to cover all fields of basic science, as well as the humanities—arts, literatures, religions. It should be especially strong in those fields where scientific progress is most needed in order to provide a better foundation for peaceful and harmonious relations among the peoples of the world and for the advancement of the economic and social well-being of mankind.

The university system might have a number of special institutes, among them possibly a World Institute of Social Technology to carry on advanced research and teaching in the practical application of the psychological and social sciences to the problems of human relations and social organization—especially those encountered in the present worldwide effort to raise economic and social levels. Such an institute could emphasize public administration, business management, development of law and justice to fit a variety of cultural conditions, diplomacy, linguistics, world organization, and methods of technical assistance.

The financing of the United Nations university system might be approached in two ways. First, each member nation could be asked to agree to contribute annually toward a capital fund for the university, this fund to be invested by the World Bank in productive developments throughout the world, the income and portions of the principal to be turned over to the university system as needed. The amount of the contribution might be one-tenth of 1 percent of the annual expenditure of each United Nations member on military defense, or, if this runs into insuperable secrecy barriers, an agreed fraction of some index like the output of armament-related industries (steel, aircraft, certain chemicals, electronics, less deductions for provable civilian uses) or simply an index of total national product. Second, by agreement the United Nations could be given exclusive future authority to tax the use of resources newly opened by science which are not at present within the jurisdiction of national states, specifically: ocean resources, polar resources, space traffic rights. This would yield little revenue at present, and national states would find it relatively painless to cede such rights to the United Nations. But over the next few decades this source of revenue might become important. It would be fitting to devote the first portion of such revenues, derived from the achievements of science, to the development of a university system dedicated to the world unity of science and to science in the service of mankind.

# APPENDIX

## Study VI. Possible Nonmilitary Scientific Developments and Their Potential Impact on Foreign Policy Problems of the United States

Stanford Research Institute, Menlo Park, Calif.

**Submission date; July 24, 1959**

*Purpose.*—This study will be an imaginative but scientifically sound examination of possible scientific developments during the next decade, with an estimate of the impact of such developments on foreign relations.

OUTLINE OF STUDY VI

I. Main findings of the research.

II. Conclusions and recommendations.

III. Main body of the study. The project will point out the possible impact of scientific developments on the foreign policy of the United States. It will consider favorable and unfavorable effects. It will extrapolate our present knowledge about scientific developments to outline the nature of typical foreign policy problems that may be faced by the United States as a result of such developments. The study will seek to assist the committee in determining what legislative action, if any, may be desired in the interest of preparing the United States to solve such potential future problems.

A. What are some scientific developments that may affect the environment in which we live? A brief discussion of several examples would include an evaluation of the probable impact of such developments on U.S. foreign relations. Examples selected may include one or more of the following:

1. Modifications of the geography through nuclear explosions or other means so as to shift the movement and distribution of air and water masses and possibly modify climatic conditions in given areas. (For example, much interest exists in the possibilities of damming narrow straits such as the Bering Strait, the Denmark Strait, or even the Norwegian Sea to delay the rapid melting of the icecap.)
2. Modifications of world meteorological conditions. (For example, what types of controls or agreements might be needed should effective control of climate be achieved?)
3. Dangerous increase in air or water pollution. (Will disposal of waste materials from large-scale use of atomic energy require international agreements?)

B. What are some scientific developments that may affect the economic pressures for higher standards of living? The discussion would include such examples as:
   1. Population control. (What new pressures may arise both in and out of the United States from significant alterations of life expectancy or from the discovery of an inexpensive, effective birth-control mechanism?)
   2. New food sources. (What is the outlook for new food sources? What international agreements might be needed to "farm the sea"?)
   3. New energy sources. (What are the prospects of using atomic, solar, tide, or wind energy? What impact on our foreign policy would a shift in the nature of energy requirements cause?)

C. What foreign policy problems may arise from increased use of disputed areas or space? The topics discussed may include one or more of the following:
   1. Mining the sea. (Will an increased use of the sea to provide food and also to provide minerals in or below it require new definitions of control and ownership?)
   2. Increased use of space. (Problems of satellite interference, interstellar debris, and space "ownership.")

D. What impact may new discoveries in the field of human communications and understanding have on the foreign policy of the United States? The discussion will include such topics as:
   1. Radio communications and problems relating to great increases in the range of radio transmission.
   2. Advances in psychological techniques (such as effect of subliminal messages, and new understanding of mass human motivation).
   3. The development of a world auxiliary language or speedy translation system.

E. In view of the nature and characteristics of the scientific developments discussed in this study and in view of their possible impact on the foreign policy of the United States, what generalizations can be made about the potential impact of scientific developments on the foreign policy of the United States?

F. What measures, if any, may be desirable to prepare the United States to solve these and similar potential problems?

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